DRILLING
AND PRODUCTION

PIPE LINE

REFINING
NATURAL GASOLINE

OUT-WEAR

Give extra service far beyond the life of ordinary valves.

•

Sizes: 2", 3", 4".

OUT-PERFORM

Actual service records prove their amazing economy.

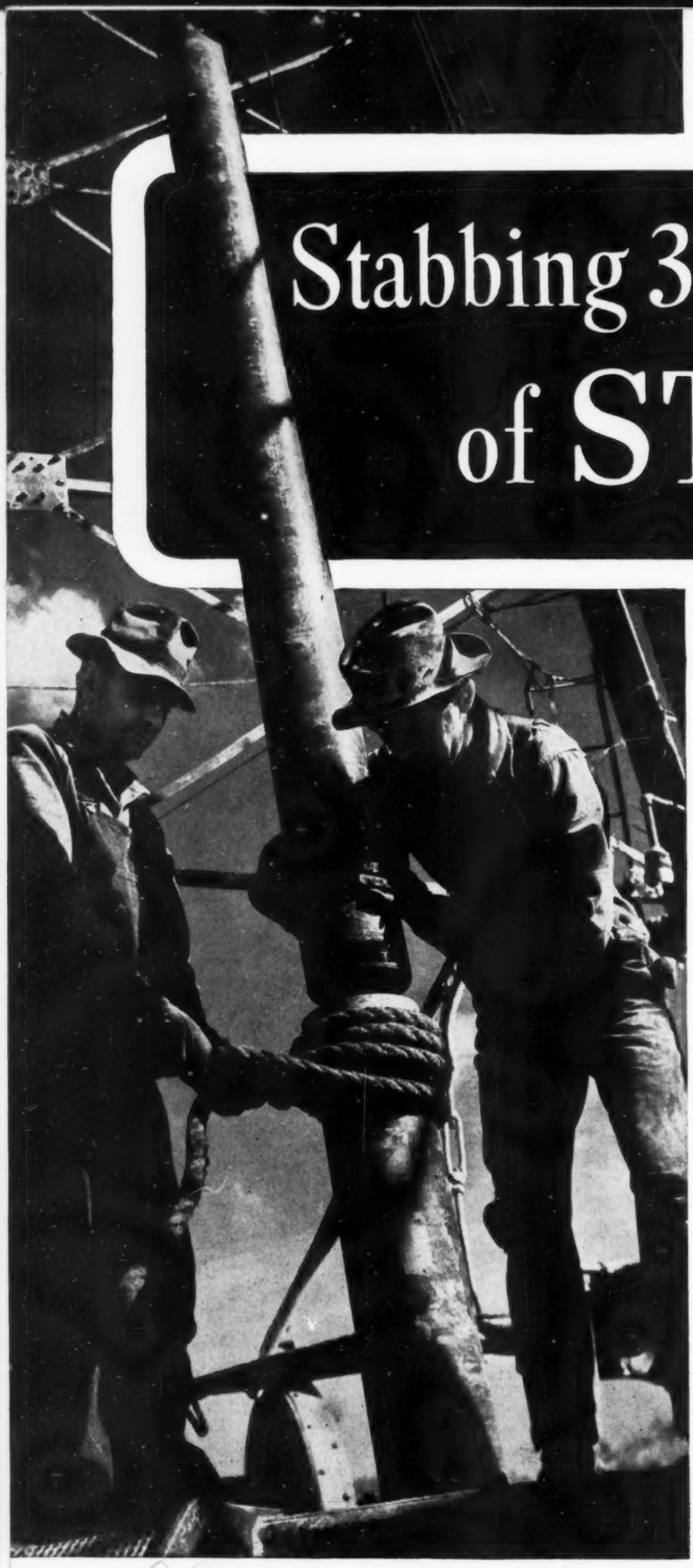
•

Pressures: 1500 to 3000 lbs.

MERCO NORDSTROM VALVE CO., *A Subsidiary of Pittsburgh Equitable Meter Co.*

MAIN OFFICE: Pittsburgh, Pennsylvania • BRANCHES: Boston, Buffalo, Brooklyn, Chicago, Columbia, S. C.; Des Moines, Houston, Kansas City, Los Angeles, Memphis, New York City, Philadelphia, San Francisco, Seattle, Tulsa

Stabbing 30-foot Bayonets of STEEL



Maybe you never thought of steel casing and tubing as weapons of war—but, figuratively speaking, every joint stabbed is a jab at the Japs.

Our ships, planes, tanks and trucks need Oil and Gasoline to hunt out our enemies and blast their hides. Our armament industries need Gas to build more mechanized fighting power.

We're here to help you stab faster than ever—with accurately-threaded, tough, strong, electric weld casing. We're ready to supply the tubing and line pipe—the alloy and stainless steels you need, too. We're producing vitally-needed steel in record-smashing tonnages—all the Steel that tens of thousands of men, 65 mills and mines and millions of dollars' worth of new furnaces and plants can produce in 24-hour-a-day *War-time Production.*

For if we supply more Steel and you produce more Oil and Gas, we can put an end to our war-hungry foes a lot sooner—and the sooner the better for all of us.

War calls for more speed and less trouble in running strings of casing and tubing, in laying pipe lines. "The Pipe of Progress," a 44-page book, shows how you get them through exclusive processes used to make Republic electric weld tubular goods. Ask for it.

REPUBLIC STEEL CORPORATION

General Offices: Cleveland, Ohio

Howard Supply Company • Republic Supply Company
Los Angeles, California • Houston, Texas
Berger Manufacturing Division • Culvert Division
Niles Steel Products Division • Steel and Tubes Division
Union Drawn Steel Division • Truscon Steel Company
Export Department: Chrysler Building, New York, New York

REPUBLIC *Electric Weld*

LINE PIPE...NORMALIZED CASING AND TUBING

Other Republic products include Sheets and Plates—Upson Bolts, Studs, Nuts and Rivets—Electrunite Heat Exchanger Tubes

☆ PROTECTING WIRE ROPE AGAINST CORROSION ☆

This is Number 11 in a series of informative articles prepared by Macwhyte Wire Rope Company. The purpose of this series is to help wire rope users in these critical times to get the longest possible service from present ropes . . . through making useful facts on rope care more widely known.

The preceding article, No. 10 in this series, pointed out the causes of wire rope corrosion, where and when it was likely to strike. This article, No. 11, tells how to guard against corrosion. This and the previous ten articles in the series is available on request on your company letterhead.

Lubrication . . . its importance

No way has yet been found to remove the "causes" of corrosion. However, there is a method of protecting wire rope against corrosive elements . . . against atmosphere, weathering, or special conditions which subject the rope to either acid or alkaline substances.

That method is . . . *thorough lubrication.*

A recent and good illustration of such protective practice is found in the automotive industry. When car makers turned their plants into war production centers they ripped out massive automobile dies and machines worth millions, carted them to parking lots for the duration. When peace comes, back to work they will go.

Meanwhile these machines and dies are being protected against corrosion by a *thick coating of grease.*

Wire ropes, too, are machines. When in use (and more so when inactive) their parts need the protection good lubrication gives. Only when protected by lubrication (which retards corrosion) will they give the best possible service. Today, when we must all conserve what we have, such protection is doubly important.

Corrosion starts as soon as wires and strands are exposed to the elements and usually starts before one is aware of it.

In its early stages, corrosion is difficult to detect. The first signs are general discoloration of the wires of the rope. As corrosion progresses, the wires will become either pitted or covered with a reddish brown substance depending upon whether the corrosion is of an acid or alkaline type.

To prevent such destruction... LUBRICATE

Destruction came to these wire ropes much too soon. It might have been prevented. At an early inspection periodic lubrication would have added countless hours to the service life of these ropes.

A *This sample,* in addition to showing evidence of wear, is very badly corroded due to having been subjected to corroding conditions of an alkaline nature.

B *Lack of lubrication* caused the wires in this rope to become rust-bound. Fractures of this character occur when suddenly picking up the load or when the rope is flexed over the sheave, because the rust-bound wires cannot properly slide by each other. Notice the wires show very little evidence of wear.

NO. 612

Curb Corrosion and Conserve Steel

Corrosion is like an incurable disease which creeps up on a person gradually. You may check the damage it is doing, but you can never repair the damage done. Eventually it leads to early death of a rope whose service life could have been so much longer . . . with ordinary care.

Today corrosion is a very real enemy, destroying vital material (steel) needed for victory. If you inspect your ropes regularly, and apply lubricants freely, frequently, you are doing your bit to defeat this wire rope saboteur and get maximum service from your wire rope.

If you have further questions on corrosion (or any wire rope problems) feel free to write us about them. Simply address Macwhyte Company, 2940 Fourteenth Avenue, Kenosha, Wisconsin. Please write on your company letterhead.

MONARCH Whyte Strand PRE-FORMED WIRE ROPE

Macwhyte's premier wire rope, famous for its strength, toughness, and internal lubrication

Made by

MACWHYTE COMPANY

2940 Fourteenth Avenue • Kenosha, Wisconsin

New York • Pittsburgh • Chicago
Ft. Worth • Portland • Seattle • San Francisco
Distributors throughout the U. S. A.

Macwhyte Company Manufactures:
MACWHYTE PREformed and Internally Lubricated Wire Rope
MONARCH WHYTE STRAND Wire Rope
MACWHYTE Special Traction Elevator Cable
MACWHYTE Braided Wire Rope Slings
MACWHYTE Cables, Tie Rods, Terminals, for Aircraft

The Petroleum Engineer. published monthly, August through June, semi-monthly in July, by The Petroleum Engineer Publishing Company, seventh floor Allen Building, Dallas, Texas. Subscription price, $2.00 per year, $3.00 for 2 years, 25c a copy. Entered as second-class mail matter May 1, 1932, at the post office at Dallas, Texas, under the Act of March 3, 1879.

Annual Number
(July 1, 1942)

THE Petroleum Engineer

VOL. XIII No.

THE PETROLEUM ENGINEER PUBLISHING CO. . . . Phone: Central-4571 . . . Seventh Floor Allen Building . . . DALLAS, TEXAS
Clarence Morris, President, 1929-40

A Magazine of Methods for Operating Me

EXECUTIVE

W. L. LOVE
President

W. T. BRYAN
General Manager and Treasurer

EDITORIAL

K. C. SCLATER
Vice-President and Editor

FRANK H. LOVE
Managing Editor

C. C. PRYOR
Associate Editor

WALLACE A. SAWDON
Pacific Coast and Foreign Editor
2062 Paramount Drive
Los Angeles, California
Telephone: Hl llside 1695

ADVERTISING

T. J. CROWLEY
Vice-Pres. and Advertising Mgr.

NEW YORK, N. Y.

ROGER MOTHERAL
7545 Kessel Street
Forest Hills, Long Island, N. Y.
Telephone: BOulevard 8-2959

CHICAGO, ILL.

E. V. PERKINS
330 South Wells Street
Telephone: HARrison 1843

LOS ANGELES, CALIF.

R. C. WIPPERMAN
518 North Sweetzer
Telephone: Webster 9617

CIRCULATION

C. R. BARRETT
Circulation Manager

CONTENTS

DRILLING AND PRODUCTION

	Page
Gravel Pre-Packed Liners *By* F. A. GRASER	36
Rotary Pressure-Drilling Practice *By* E. V. FORAN	44
Mud Analysis Logging in California Fields *By* WALLACE A. SAWDON	48
Arkansas' Oil and Gas Industry Managed on Engineering Basis *By* ALEC M. CROWELL	55
Submersible Magnetic Strain Gauge *By* E. H. LAMBERGER *and* B. F. LANGER	64
Rate of Penetration Record Facilitates Drilling *By* WALLACE A. SAWDON	71
Automatic Instrument Aids Mud and Well Control *By* JOHN B. WARREN, JR.	76
Gravel-Packing Wells to Increase Production Efficiency *By* LESTER C. UREN	81
Determining Productivity Index of Pumping Well by Copper Tubing Method	115
Oil Reservoir Drainage Increased by Intermittent Air-Injection *By* F. R. COZZENS	120
Drilling in Swamp Area of Louisiana Gulf Coast Simplified by Use of Barges *By* C. C. PRYOR	122
The Stripper Well Problem *By* JAMES F. WEILER	162

REFINING AND NATURAL GASOLINE MANUFACTURE

Simplified Method of Processing Characterizes Cycling Plant *By* FRANK H. LOVE	33
Economics of Design and Operation for Pressure Maintenance and Condensate Recovery *By* E. O. BENNETT, C. R. WILLIAMS, *and* G. O. KIMMELL	99
Protection of Natural Gasoline Plants from Air Raids *By* DON ATTAWAY	142
Conversion of Gasoline Plants to Increase *Iso*butane Extraction *By* W. L. RIFENBERICK	150
Evaluating Petroleum Lubricants *By* J. W. POOLE	175
Adaptation of the Centrifugal Pump to Refinery Use *By* R. G. LOVELL	179

OIL AND GAS TRANSPORTATION

Methods of Cleaning Corrosion Coupons *By* C. E. LEE *and* A. C. ALTER	92
Bonding Pipe Lines as Protection Against Electrolysis *By* E. E. CLAGGETT	128
Machine Shop Plays Important Role in Maintaining Compressor Station Equipment *By* W. E. NESTOR *and* G. H. McKAY	136
When Should a Pipe Line be Coated? *By* STARR THAYER	158

GENERAL

Editorial	18
Oil Outlook for 1942 Profoundly Affected by War Restrictions *By* H. J. STRUTH	23

MEMBER A. B. C.—A. B. P. (The articles in *The Petroleum Engineer* are indexed in the *Industrial Arts Index*, New York, N

Copyright 1942, by The Petroleum Engineer Publishing Company

Hazard Lines are Uniform

Reading Time 38 Seconds

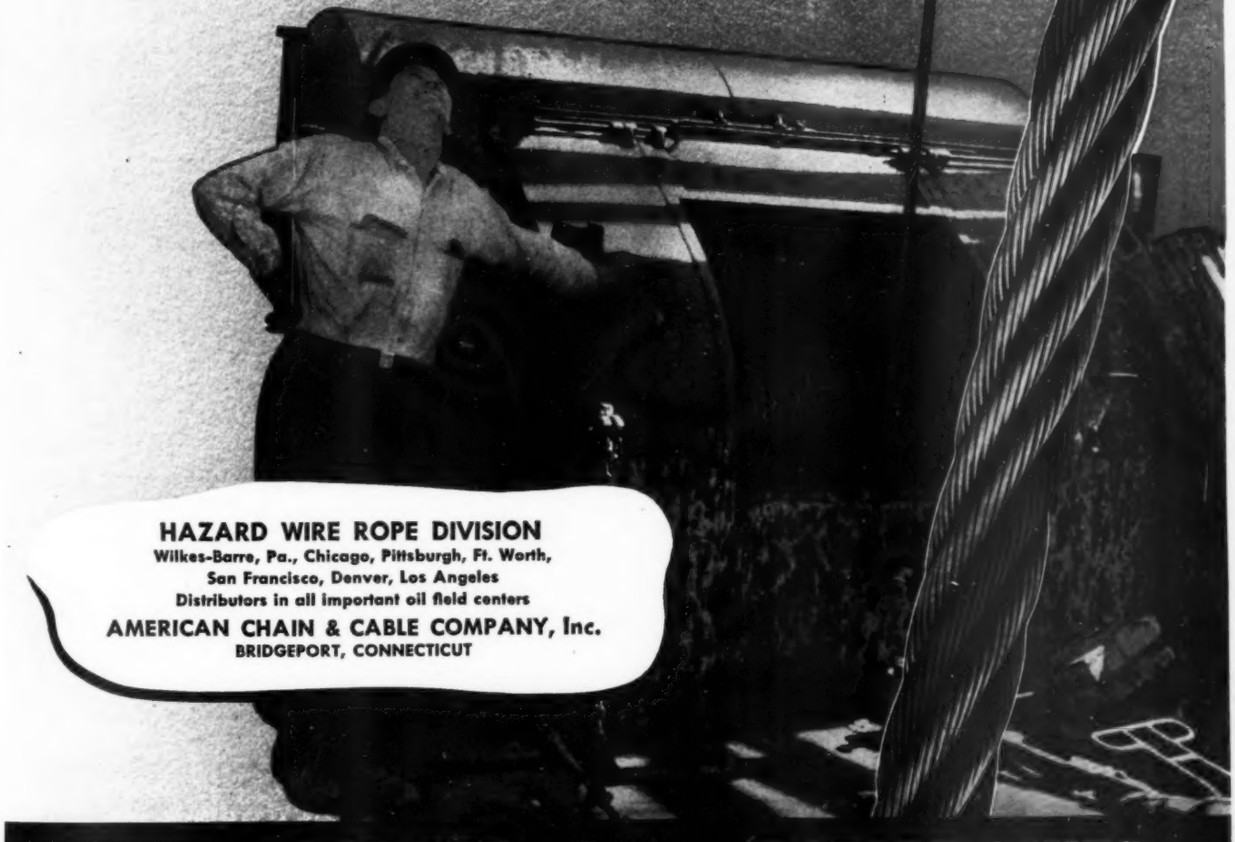
●Ever since 1846 Hazard has been making quality wire rope. That's a long time—a lot of experience. A product *has* to be uniform in high quality to maintain its name through three generations. It *has* to be uniform to keep customers coming back for Hazard ropes, *continuously*, for 30, 40, and 50 years. A product *has* to be uniform in quality to merit such customer loyalty.

Now as to specific ropes:—

HAZARD LAY·SET Preformed green strand is more and more becoming the standard rotary drilling line in all fields because it lasts longer—resists whipping—makes possible faster round trips. LAY-SET PREFORMED handles easier, spools better, *is safer*. And when you use green strand LAY-SET, you know it is made of Improved Plow Steel—the long-life, greater-dollar-value line.

HAZARD "NONPARELL" has long been preferred by cable tool drillers. This is one of the lines that is backed by nearly a century of wire rope-making experience—known to all the "old timers" as well as the younger drillers, tool pushers and superintendents as the line that gets the job done.

GREEN SIGNIFIES SAFETY



HAZARD WIRE ROPE DIVISION
Wilkes-Barre, Pa., Chicago, Pittsburgh, Ft. Worth, San Francisco, Denver, Los Angeles
Distributors in all important oil field centers
AMERICAN CHAIN & CABLE COMPANY, Inc.
BRIDGEPORT, CONNECTICUT

HAZARD LAY·SET *Preformed* ROTARY LINES

Editorial

DURING the first six months of 1942 momentous changes have occurred in the petroleum industry. Exigencies of war that have arisen have had to be met. Restrictions in the use of steel, tanker sinkings, and shortage of rubber have culminated in the imposition of stringent demands on the petroleum industry that were undreamed of a few months ago.

Material shortages have caused drastic curtailment of drilling and producing operations. Thus far, the industry has been able to meet the demand for crude oil without trouble, but the situation with respect to new drilling to increase the nation's oil reserves has gravely deteriorated.

Tanker sinkings have caused transportation difficulties and led to serious shortages of petroleum products on the Eastern Seaboard. Surpluses of crude oil have accumulated in other parts of the country near the points of production and have impeded field operations.

The rubber shortage has compelled the rationing of gasoline in seventeen eastern states, which may be extended to all states. The impact on the economy of the oil industry should gasoline rationing become nationwide—as it surely will—will be tremendous.

Thanks to the conservation practices that have been in effect, the producing branch of the industry has so far been able to withstand the devastating effects produced by these developments.

Though it is futile to predict what is in store for the remaining half of 1942, it would be imprudent not to heed the trends that have developed during the first half of this year.

According to factual data that reflect the effect of war restrictions and contained in an article in this issue, it is indicated that the total additions to proved oil reserves in the United States this year may not exceed one billion barrels. Last year the total new reserves discovered was approximately two billion barrels of which all but half a billion was accounted for by extensions and revisions to previously discovered pools. The discovery rate continues to decline with increasing sharpness, and the percentage of dry holes drilled has also increased. It is evident, therefore, that the restrictions under which the industry has been operating have failed of their purpose. If the existing trend continues, the amount of new drilling this year will fall far short of the 19,000 wells that it was estimated would be necessary to maintain reserves and production.

Although there is no shortage of crude oil for present needs, the immediate necessity of reversing the trend of discovery of new oil reserves is obvious. Failure to arrest the sharp decline that has occurred may aggravate an already serious situation, particularly should it reach the point that it becomes necessary to draw heavily on fields now producing.

It is well to recognize also that in the refining and natural gasoline branches of the industry, new projects now under construction to provide raw materials for the manufacture of synthetic rubber, toluene, and high-octane aviation gasoline, will, when completed, augment the demand for crude oil. Will the industry be prepared to meet this demand?

The avowed purpose of Order M-68 was to enforce the fullest utilization of steel and other critical materials so that the greatest quantity of oil could be discovered or produced per unit of steel expended. These ends have not been accomplished.

Changed conditions necessitate liberalizing the restrictions on drilling that now prevail. Transportation has been disrupted to such an extent that the availability of oil to transportation facilities must be considered. Some types of oil are more desirable than others for war needs; so this factor must also be considered. In other words, availability of oil to transportation and the type and quantity of oil produced become paramount considerations that may transcend well-spacing considerations. What good is it to discover new oil reserves or to develop new reserves in fields already producing, if the oil cannot be made available within a reasonable length of time and without added expenditure of steel and other critical materials in order to transport it to the point where it is to be used? Why drill in areas that produce a type of oil that is not needed or may not be available in sufficient quantity per unit of critical material expended?

Selective drilling based on availability to market and the type and quantity of oil that may be produced, must eventually be given consideration; strict adherence to drilling patterns or well-spacing requirements to the exclusion of other important factors is a mistake, and defeats the very purpose it was hoped to accomplish. Modification of drilling and producing restrictions will become imperative if the trend in rate of discovery of new reserves is not reversed. Continued lack of adequate oil reserves will lead inevitably to producing existing fields at a rate that will cause large underground losses.

There must also be taken into consideration the adjustments that will be necessary when the completion of new transportation facilities now in course of construction are completed.

Authorities cannot longer delay taking action that will ensure the discovery of adequate additional oil reserves to enable the industry to meet the ever-increasing demands that will be made on it. . . . K. C. S.

THE Petroleum Engineer
Annual Number

Oil Outlook for 1942 Profoundly Affected by War Restrictions

☆ Slump in well completions, drilling operations, and sharp upturn in dry hole ratios lift oil finding cost to new high level—Substantial reduction in crude output likely if gasoline rationing is extended

PETROLEUM ENGINEER Exclusive Feature

by H. J. Struth

Petroleum Economist

THE results of the oil industry's operations for the first half of 1942 leave no doubt of the important part it is playing in the nation's war effort. The facts make it evident that the oil industry has launched an all-out program of providing our armed forces with essential war products despite enforced loss of normal markets, the necessity of curtailing its steel requirements to an irreducible minimum, and the absorption of huge losses* in transportation costs entailed by overland movements of petroleum products to the Atlantic seaboard.

The effect upon oil producers of rationing of motor gasoline along the Atlantic seaboard in the first half of this year has been a reduction in crude oil demand of about 120,000 bbl. per day. However, the probable effect of nation-wide rationing, threatened by the urge to save rubber, may mean a reduction in crude oil demand in the last half of this year of perhaps 700,000 bbl. a day under the demand experienced during the first half of this year.

*East Coast gasoline prices were advanced 2½ cents per gal. and fuel oil 2 cents per gal. June 29 to offset these losses. (By Leon Henderson, Office of Price Administration.)

Effect of Priorities

The effect of priorities on steel required for drilling in the first half of this year is reflected by a decline of more than 37 percent in new oil-well completions and a drop of 55 percent in new drilling operations. The alarming result of this slump in drilling is shown by the fact that the dry hole ratio in June of this year averaged more than 31 percent against less than 24 percent a year ago.

Fig. 1 shows the changes in the petroleum industry's operations for the first half of this year compared with the corresponding period of last year. As a result of drilling operations being confined largely to wildcat wells, the dry hole ratio for the first half of this year registered a net gain of more than 24 percent. On the basis of current operations, however, the dry hole ratio is actually 30 percent greater than a year ago.

H. J. STRUTH

A quarter of a century in the oil business is "Hank's" proud claim—He has been analyzing the oil situation for more than two decades and has written more than a million words on the economics of the petroleum industry—Is a native of New York, attended New York University, and began his career in the oil industry with the Empire Companies, at Bartlesville, Oklahoma, in 1917—Has resided in Texas more than 14 years, formerly in Houston and now at Dallas, where he is economist for the Texas Mid-Continent Oil and Gas Association.

Although the production of crude oil in the first half of this year showed a gain of more than 2 percent, runs of crude through refinery stills declined nearly 3 percent. The decline in crude oil runs, however, was offset by a substantial increase in the use of natural gasoline, which accounts for the step-

ped-up output of this product. The increase in natural gasoline production of nearly 42 percent over last year reflects the importance of this product in the war demand for aviation gasoline.

Fuel Oil Increase

Of paramount importance to oil producers is the revamping of refinery operating schedules for the production of greater yields of fuel oil and reduced yields of gasoline. As the situation looks now, refinery gasoline yields may be reduced to about 35 percent, against 44.6 percent at the beginning of the year, whereas residual fuel oil yields may be increased to 30.5 percent, against 24.6 percent at the beginning of the year. With gasoline yields reduced about 9 percent or more below normal, the demand for crude oil will not be so severely reduced as might otherwise result from the rationing of motor gasoline.

The demand for gasoline in the first half of this year does not reflect the full effect of rationing in the 17 Eastern States and the District of Columbia. The net decline in motor fuel demand of 2.3 percent under the corresponding period of last year is a compromise between the first quarter and the second quarter of the year. The preliminary figures indicate that the demand for motor fuel in June was about 12 percent below a year ago, whereas the forecast of the U. S. Bureau of Mines predicts a drop of 18 percent in July of this year.

Figures for the first half of this year bear out the shortage developing in the eastern fuel oil situation. Stocks of all fuel oils were reduced in the first half of this year by more than 26,000,000 bbl. as a result of an increase in demand of more than 23,000,000 bbl. over the first six months of last year. (See Table 3.) The reduction in stocks of motor fuel, fuel oil, and other products in the first half of this year resulted in a net reduction in stocks of all refined oils amounting to more than 40,000,000 bbl. This reflects the extent to which the national war program is related to the war effort of the petroleum industry.

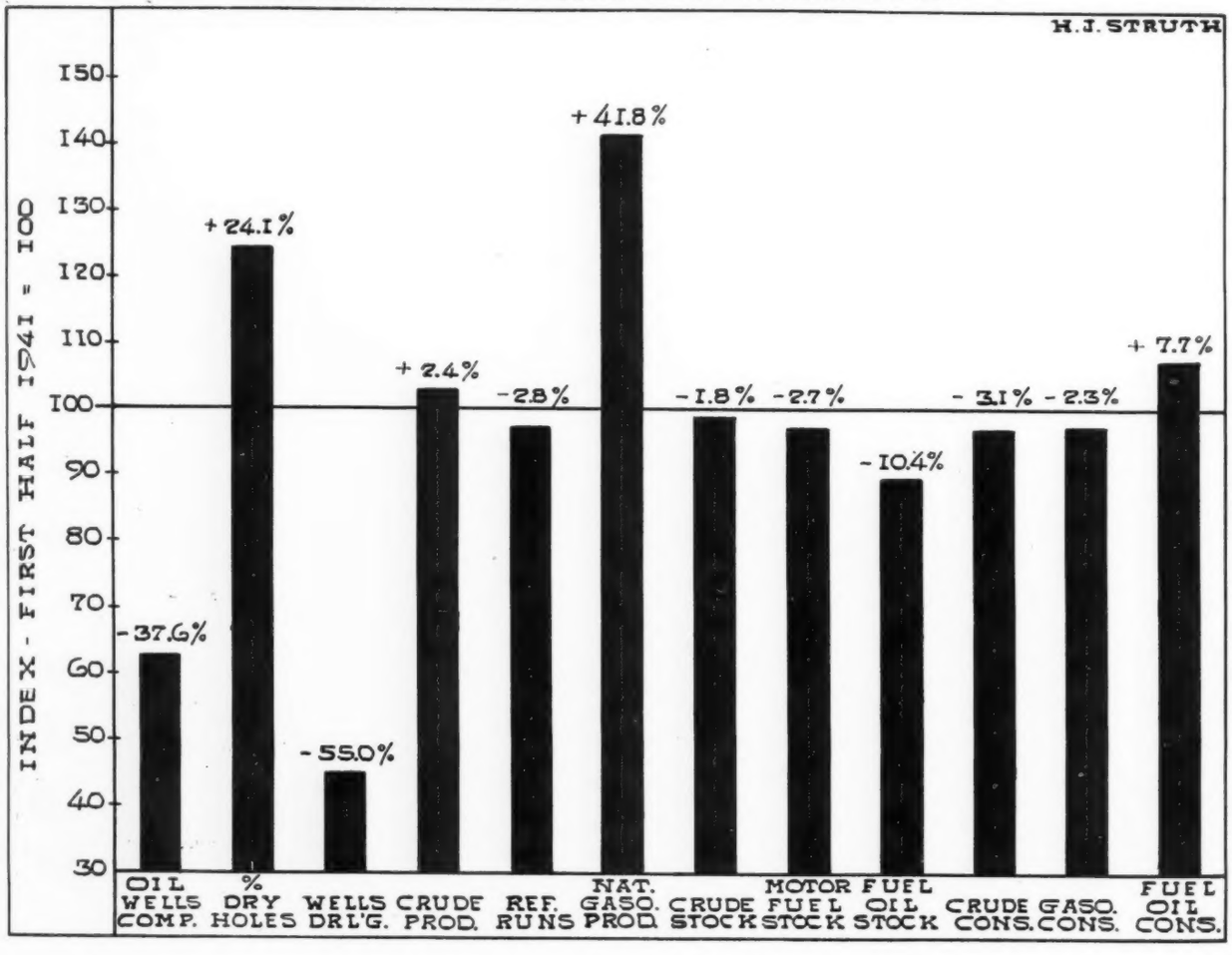
Crude Oil Prices

Prices of crude oil were stabilized at last year's levels during the first half of this year. The only change was a 25-cent advance in the price of Pennsylvania crude oil. At the same time prices of refinery products moved upward, with the exception of the Mid-Continent area, where prices were generally lower than at this time last year. Crude oil prices in that area are the subject of much controversy; operators there contend that reduced allowables are increasing unit operating costs.

Analysis of the crude oil situation for the first half of this year and last year, as shown in Table 2, indicates a sharp reduction in the quantity of foreign crude oil imported into the United States. Although figures on imports and exports are no longer available, it is apparent from the summation of all known data that the balance in foreign trade in the first half of this year was

Fig. 1. United States oil situation—First half of 1942 compared with first half of 1941

Columns are relative to heavy horizontal line (100), which represents level of each factor during the first half of 1941. Percentages show increase or decrease compared with corresponding period of 1941. Details are presented in Table 1



in favor of the United States to the extent of more than 12 million barrels. In the first half of last year, imports of crude oil exceeded exports by more than six million barrels. It is quite likely that the export movement has shifted to Canada, offsetting former imports from South America.

Although national crude oil production increased 2.4 percent in the first half of this year over the corresponding period of last year, decreases totaling more than 13,000,000 bbl. were recorded by Texas, Oklahoma, Illinois, and Michigan. Against this, increases totaling more than 30,000,000 bbl. were recorded by Louisiana, Kansas, California, Eastern States, and other states. (Table 4—Fig. 2.)

Preliminary production figures for June, compared with January of this year, show that Texas oil operators sustained a reduction in output of about 343,000 bbl. per day. By comparison Louisiana, Oklahoma, Illinois, and New Mexico showed a combined reduction of 283,000 bbl. a day, whereas the Eastern States reported a combined increase of 13,000 bbl. per day.

TABLE 2
United States Crude Oil Situation
First half of 1942 and corresponding period of 1941

	1942*	1941
Stocks, January 1	257,063,000	276,615,000
Production	683,588,000	667,338,000
Total	940,651,000	943,953,000
Refinery runs	650,359,000	668,663,000
Other consumption	12,500,000	11,725,000
Stocks, June 30	265,000,000	269,786,000
Total	927,859,000	950,174,000
Exports above imports	12,792,000	.....
Imports above exports	.....	6,221,000
Indicated total demand	675,000,000	696,181,000

*Preliminary, subject to final revision.

Drilling

Fig. 3 shows the effect of drilling restrictions in the first half of this year, compared with the corresponding period of last year. The net effect of confining new drilling largely to wildcat operations has been to boost the dry hole ratios to a substantial degree. It will be noted in Table 5 that well completions in the United States showed a decline under last year of 3867 wells, including oil wells, gas wells, and dry holes.

A study of field operations during this six-month period shows that well completions in June were reduced to about half the rate recorded in January. If completions recorded in the second

TABLE 3
United States Fuel Oil Situation
First half of 1942 and corresponding period of 1941

	1942*	1941
Stocks, January 1	133,121,000	132,244,000
Production	266,000,000	257,825,000
Transfers	12,350,000	6,022,000
Total	411,471,000	396,091,000
Domestic consumption	(a)	280,640,000
Stocks, June 30	107,000,900	119,386,000
Total	(a)	400,026,000
Excess imports over exports	(a)	3,935,000
Total demand	317,000,000	294,299,000

*Preliminary, subject to final revision.
(a) Not available.

TABLE 1
United States petroleum situation
First half of 1942 and corresponding periods of 1940 and 1941

	First half 1940	First half 1941	First half *1942	Index 1941–100	Percent increase or decrease
Total wells drilled	14,478	13.234	9,367	70.8	—29.2
Oil wells	10,441	8.868	5,538	62.4	—37.6
Gas wells	905	1,249	1,088	87.1	—12.9
Dry holes	3,132	3,117	2,741	87.9	—12.1
Percent dry holes	21.6	23.6	29.3	124.1	+24.1
Wells drilling, June 30	3,796	4,191	1,879	45.0	—55.0
Crude production, bbl.	687,901,000	667,338,000	683,588,000	102.4	+ 2.4
Daily average, bbl.	3,780,000	3,687,000	3,776,000		
Refinery runs, bbl.	645,408,000	668,663,000	650,359,000	97.2	— 2.8
Daily average, bbl.	3,566,000	3,694,000	3,593,000		
Natural gasoline production, bbl.	26,341,000	29,621,000	42,000,000	141.8	+41.8
Daily average, bbl.	146,000	164,000	232,000		
Crude oil stocks, bbl.:					
January 1	252,240,000	275,985,000	257,063,000	93.1	— 6.9
June 30	275,305,000	269,786,000	265,000,000	98.2	— 1.8
Change in stocks	+23,065,000	— 6,199,000	+ 7,937,000		
Motor fuel stocks, bbl.					
January 1	81,722,000	83,607,000	90,688,000	108.5	+ 8.5
June 30	93,276,000	88,730,000	86,330,000	97.3	— 2.7
Change in stocks	+11,554,000	+ 5,123,000	— 4,358,000		
Fuel oil stocks, bbl.					
January 1	126,008,000	132,244,000	133,121,000	100.7	+ 0.7
June 30	124,733,000	119,386,000	107,000,000	89.6	—10.4
Change in stocks	— 1,275,000	—12,858,000	—26,121,000		
All refined stocks, bbl.					
January 1	268,109,000	282,265,000	290,375,000	102.9	+ 2.9
June 30	283,905,000	276,477,000	250,000,000	90.4	— 9.6
Change in stocks	+15,796,000	— 5,788,000	—40,375,000		
Total crude demand, bbl.	682,978,000	696,181,000	675,000,000	96.9	— 3.1
Daily average, bbl.	3,773,000	3,846,000	3,729,000		
Total gasoline demand, bbl.†	278,622,000	318,255,000	311,004,000	97.7	— 2.3
Daily average, bbl.	1,539,000	1,758,000	1,718,000		
Total fuel oil demand, bbl.	253,944,000	294,299,000	317,000,000	107.7	+ 7.7
Daily average, bbl.	1,403,000	1,626,000	1,751,000		
Crude oil prices, June 30					
Mid-Continent, 36 gr	$1.02	$1.17	$1.17	100.0	0
East Texas	1.10	1.25	1.25	100.0	0
Pennsylvania, Natural Transit	2.25	2.75	3.00	109.0	+ 9.0
California, Signal Hill, 26 gr	0.99	1.11	1.11	100.0	0
Refinery product prices, June 30					
U. S. motor gasoline, Group 3	4⅜	6	5⅝	93.7	— 6.3
U. S. motor gasoline, New York	6	7½	9.2	122.7	+22.7
U. S. motor gasoline, Gulf Coast	4¼	5½	5¾	104.5	+ 4.5
U. S. motor gasoline, California	5	5¾	6¼	108.7	+ 8.7
Kerosene, 41-43, Group 3	3⅜	4⅝	4⅝	100.0	0
Kerosene, New York	5.4	5.2	5.7	109.6	+ 9.6
Furnace oil, Group 3	3⅛	3⅞	3½	90.4	— 9.6
Bunker C. fuel oil, New York	$1.35	$1.35	$1.80	133.3	+33.3
Natural gasoline, Group 3	1½	3⅛	2⅛	70.3	—29.7
Natural gasoline, California	5¼	4½	2⅜	47.1	—52.9

*–Preliminary, subject to final revision.
†–Does not include aviation gasoline.

TABLE 4

Crude oil production of leading oil states
First half of 1942 and corresponding period of 1941

State	1942*		1941	
	Total	Daily	Total	Daily
Texas	241,793,000	1,336,000	243,220,000	1,344,000
Louisiana	57,406,000	317,000	55,325,000	306,000
Oklahoma	70,682,000	391,000	75,875,000	419,000
Kansas	44,957,000	248,000	37,612,000	208,000
Illinois	58,460,000	323,000	60,954,000	337,000
California	114,725,000	634,000	111,849,000	618,000
New Mexico	14,468,000	80,000	19,127,000	106,000
Pa., W. Va., Ohio, Ky., Mich., N. Y	27,856,000	154,000	23,297,000	129,000
All other	53,241,000	294,000	40,079,000	221,000
Total U. S.	683,588,000	3,776,000	667,338,000	3,687,000

*Preliminary, subject to final revision.

TABLE 5

Drilling operations of leading oil states
First half of 1942 and corresponding period of 1941

	Year	Oil	Gas	Dry	Total	Percent dry
Texas	1942	1,976	108	860	2,944	29.2
	1941	3,324	139	1,114	4,577	24.5
California	1942	222	18	147	387	38.0
	1941	474	7	102	583	17.5
Oklahoma	1942	297	52	282	631	44.7
	1941	537	89	313	939	33.3
Louisiana	1942	344	18	163	525	31.0
	1941	486	48	224	758	29.5
Illinois	1942	473	8	349	830	42.0
	1941	1,117	5	395	1,517	26.0
United States	1942	5,538	1,088	2,741	9,367	29.3
	1941	8,868	1,249	3,117	13,234	23.6

(Data for 1942 preliminary, subject to final revision)

quarter of this year serve as an index of what to expect in the last half of the year, it is likely that the industry may drill only about 6500 wells during the last half. This implies that the number of holes drilled in 1942 will probably not exceed 16,000, against nearly 30,000 holes drilled in 1941.

Under existing conditions it is likely that the dry-hole ratio will average about 32 percent this year, which means that the industry will drill about 5200 dry holes. This sharp increase of about 8 percent in dry-hole ratio projected for this year is based upon trends recorded for May and June. The alarming conclusions reached by this study are vitally important to the oil industry's future outlook and particularly as they may affect the industry's war effort. The facts make it apparent that present restrictions in drilling are perhaps too severe and if continued for the remainder of this year may prove to have defeated their purpose.

Dry-Hole Ratios

Following are the dry-hole ratios recorded for May and June of this year in five leading states:

State	*Dry-hole ratios May percent*	*June percent*
Texas	30.7	35.3
California	48.3	39.4
Oklahoma	47.7	51.1
Louisiana	30.9	25.6
Illinois	44.1	51.7

These results emphasize the need for careful study of drilling patterns in relationship to existing proved reserves. Such studies would undoubtedly show the advisability of proving extensions to comparatively recent discoveries, rather than neglecting such opportunities in order to explore unproved ter-

Fig. 2. Changes in crude oil production of leading states

Shows percentage increase or decrease in crude oil production for first half of 1942, compared with first half of 1941. Eastern represents combined production of Pennsylvania, West Virginia, Ohio, Kentucky, Michigan, and New York. Details are shown in Table 4

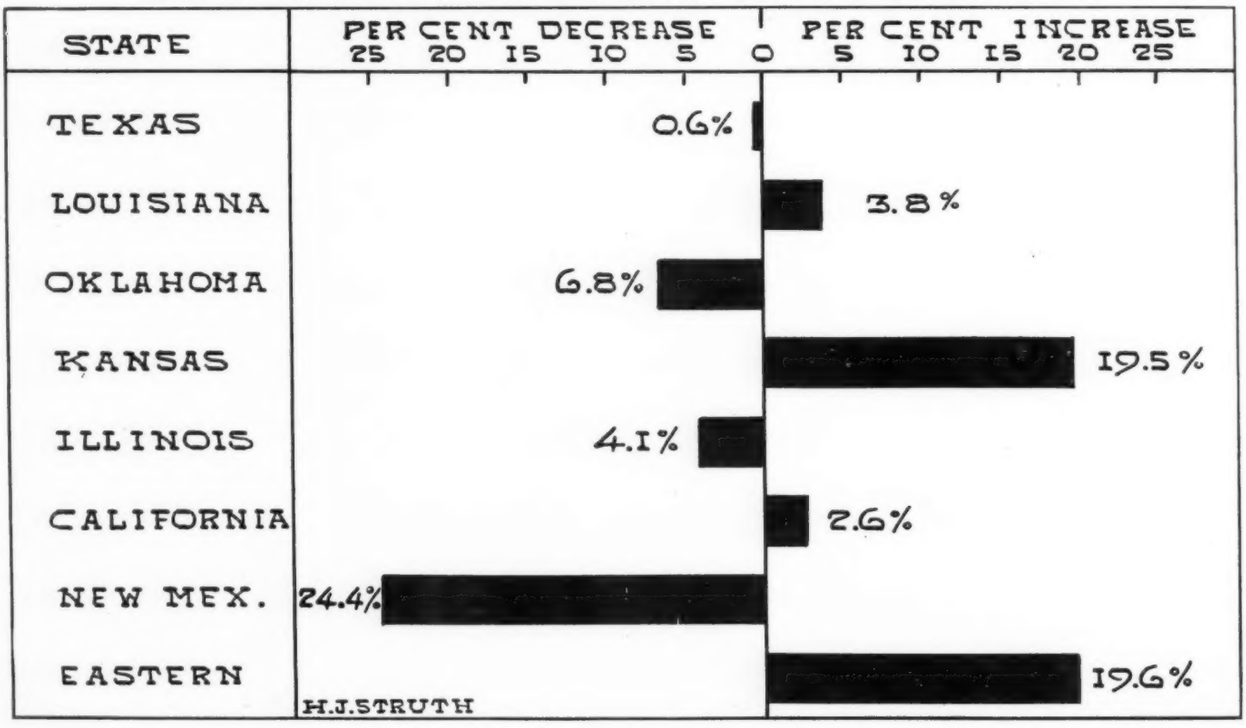


TABLE 6

Wells Drilling at End of First Half of 1942 and 1941

	First half 1942*	First half 1941	Increase or decrease
Texas	500	1107	— 607
California	95	190	— 95
Oklahoma	185	326	— 141
Louisiana	135	215	— 80
Illinois	200	351	— 151
United States	2312	4191	—1879

*Preliminary, subject to final revision.

TABLE 7

United States Gasoline Situation

First half of 1942 and corresponding period of 1941

	1942*	1941
Stocks, January 1	90,688,000	83,647,000
Production	306,646,000	323,338,000
Total	397,334,000	406,985,000
Stocks, June 30	86,330,000	88,730,000
Indicated demand	311,004,000	318,255,000
Exports over imports	(a)	9,421,000

*Preliminary, subject to final revision.
(a) Not available.

ritory. It is obvious that the high dry-hole ratios experienced in recent months are accumulating tremendously high costs against possible future oil discoveries sought in drilling unproved areas. Furthermore, such results are not conducive to the maintenance of adequate future reserves.

The extent to which drilling restrictions have affected new drilling operations is shown in Figs. 3 and 4. A preliminary check of new operations as of June 30 indicated that the industry had begun 2312 new wells. This compares with 4191 wells drilling on June 30, 1941, a decline of 55 percent. Louisiana and Illinois showed declines in new drilling of 63 percent and 57 percent, respectively; Texas, California, and Oklahoma operations were off 45 percent, 50 percent, and 43 percent, respectively. On the basis of recent results it is likely that at least 900 of these new tests will prove to be dry holes.

Gasoline Rationing

Gasoline rationing on a nationwide basis, to conserve rubber, is a question of vital concern to the nation as well as to the oil industry. If the rationing that is now in force in the eastern states is extended to the rest of the nation, the

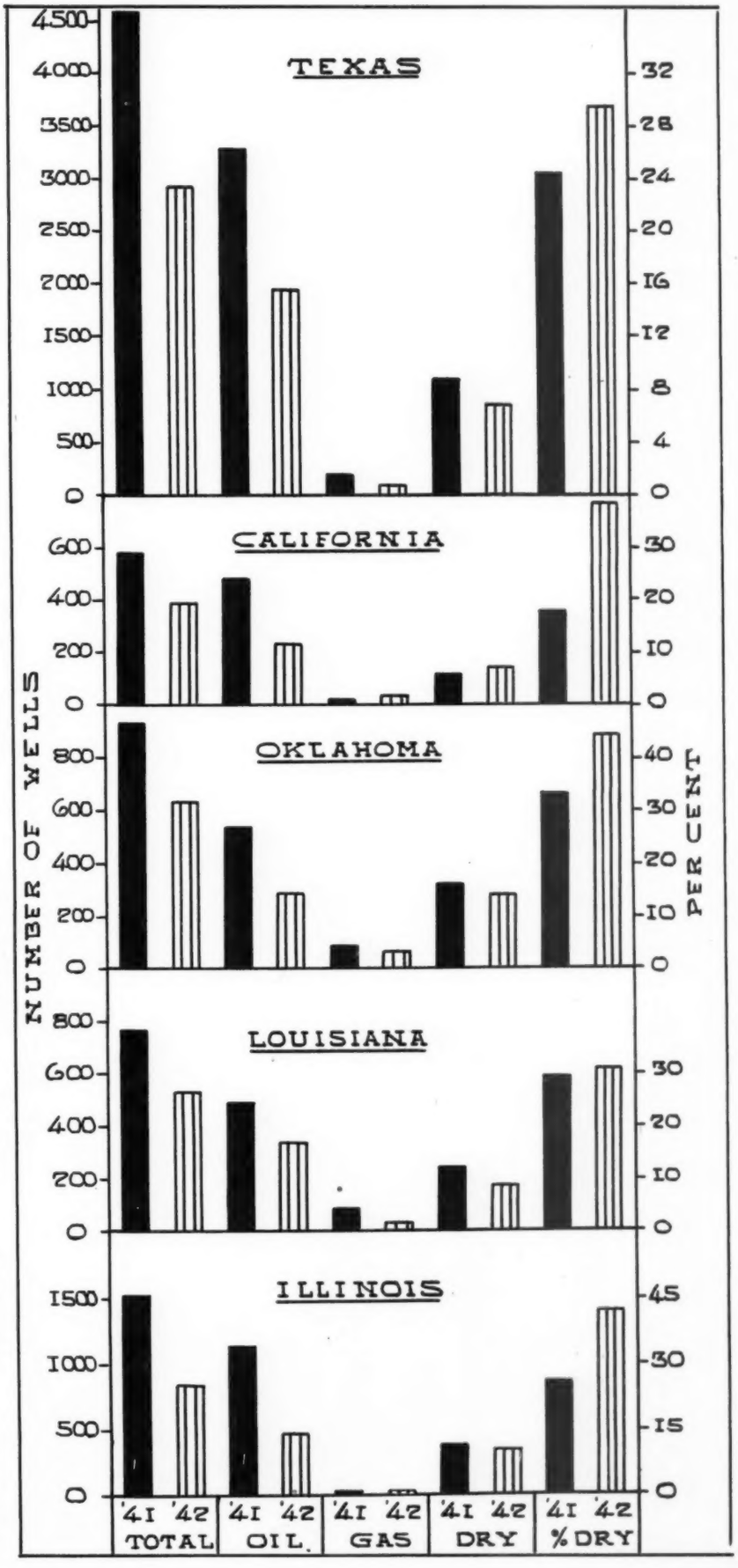


Fig. 3. Well completions, first half of 1941-42—Five leading states

The effect of restricted drilling, primarily for wildcat operations, is reflected by the sharp upturn in the percentage of dry holes drilled. Details are shown in Table 5

loss in normal markets for motor fuel to the oil industry would undoubtedly prove a serious handicap to its war effort. Whether nationwide rationing is adopted or not, there is serious doubt of the wisdom of such action. At any rate, there are many who believe that nationwide rationing would prove detrimental to existing war production schedules of the oil industry.

The figures presented in Table 7 make it apparent that there is no shortage of motor fuel. In fact, analysis of motor fuel supplies shows that refining and shipping centers are overstocked but lack of adequate transportation facilities have caused serious shortages on the East Coast. The national motor fuel situation shows a total supply of this product in the first half of this year of 397,334,000 bbl., against last year's total supply of 406,985,000 bbl. These figures do not include aviation gasoline. On the basis of current total consumption estimates, the supply of motor fuel in storage in the United States on June 30 was sufficient at present rates of consumption to last 48 days, whereas stocks on hand a year ago were equivalent to 45 days' supply.

TABLE 8

Probable course of gasoline demand under partial and nationwide rationing

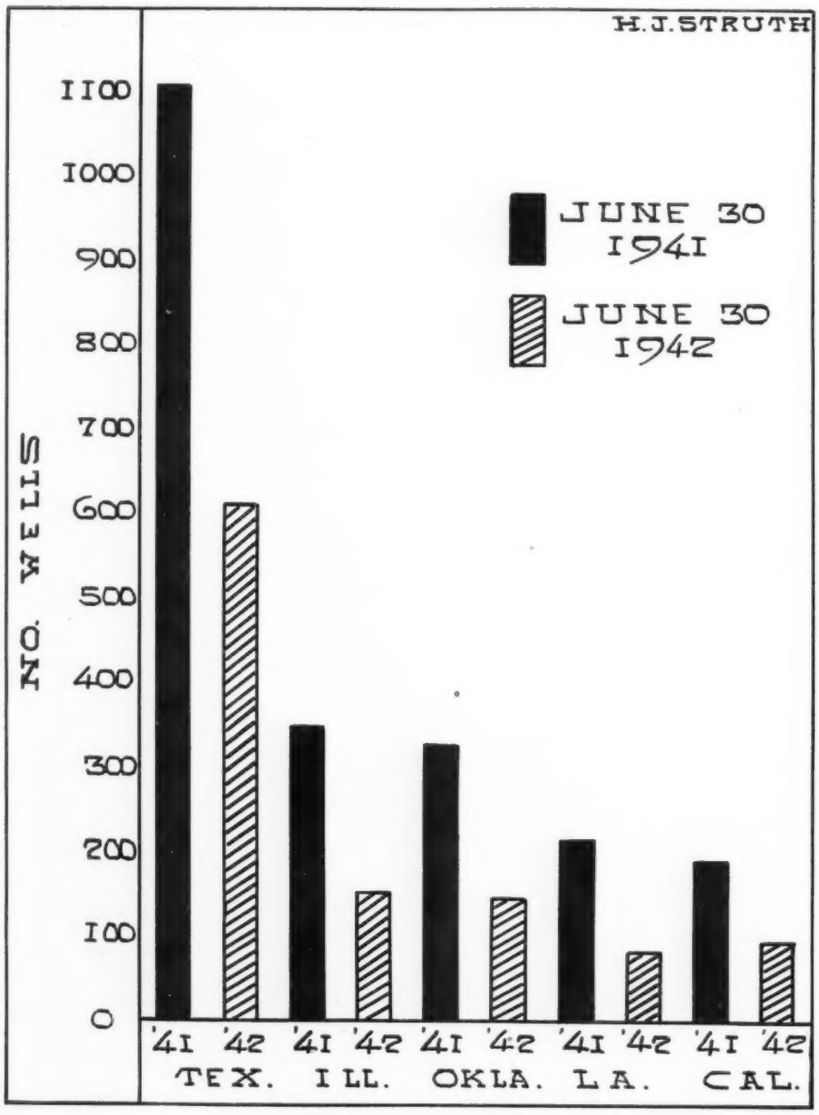
(Data based upon studies of present effect of rationing in 17 Eastern States and District of Columbia and the application of such data to all states in the event nationwide rationing is adopted.)

	Bbl.
Indicated total consumption, first half of 1942	311,004,000*
Actual consumption, first half of 1941	318,255,000
Decrease (2.3 percent)	7,251,000
Year 1942 projected under partial rationing	593,847,000
Actual consumption, year 1941	684,000,000
Decrease (13.2 percent)	90,153,000
Year 1942 projected on basis of nationwide rationing	529,804,000
Decrease (22.5 percent)	154,196,000
Last half of 1942 projected on basis of nationwide rationing	218,800,000
Actual consumption, last half of 1941	365,845,000
Decrease (40.2 percent)	147,145,000

*Preliminary, subject to final revision.

Fig. 4. Effect of war and priorities on new drilling operations

Solid columns represent wells drilling June 30, 1941. Shaded columns show by comparison the approximate number of new wells drilling at the end of the current half-year. Details are shown in Table 6



It is difficult to predict with any degree of accuracy what the demand for motor fuel in the United States will be this year. Preliminary figures for the first half of this year show a decrease in total demand, exclusive of aviation gasoline, of about 7,250,000 bbl., which represents a decline of 2.3 percent compared with the first half of last year. If gasoline rationing is extended to all states in the near future, however, it is probable that the net loss in gallonage for all this year would amount to at least 22.5 percent. This may mean a net loss to the oil industry in the last half of this year, below the corresponding period of last year, of more than 40 percent. (See Table 8.) As the use of motor fuel as well as aviation gasoline by our armed forces is a closely guarded military secret, there is no way of predicting how much of this loss in motor fuel gallonage will be offset by military requirements.

Gasoline Consumption

Under gasoline rationing as it is now practiced in the 17 Eastern States and the District of Columbia, the average consumption of motor fuel per car, including exemptions, amounts to about 5 gal. per week. As these states have 36 percent of the nation's motor cars it is likely that the consumption of motor fuel by automobiles in that area will amount, roughly, to 1,250,000,000 gal. over the remainder of this year. If this experience is applied to all the nation's 28,000,000 automobiles, assuming that 75 percent of the cars will be strictly rationed at 3 to 4 gal. per week and 25 percent were permitted to use an average of 10 gal. per week, the demand for the last half of this year by motorists would approximate 3,500,000,000 gal. If we add to this about 5,750,000,000 gal. for trucks, busses, and other

requirements, the total gallonage for the last half of this year would be about 9,250,000,000 gal. This totals about 218,800,000 bbl. of gasoline consumption in the last half of this year, under nationwide rationing. Thus, with an indicated consumption in the first half of the year of 311,004,000 bbl. the total consumption this year under nationwide rationing would be somewhere in the neighborhood of 530,000,000 bbl. against the 1941 consumption figure of 684,000,000 bbl. This would constitute a decrease in consumption this year of 22.5 percent.

The effect of nationwide gasoline rationing is expressed graphically in Fig. 5, showing comparative results for the first half of this year and last year and projecting the probable course of motor fuel consumption on a partial rationing and a national rationing program. On the basis of calculations cited above, the demand for motor fuel during the last half of this year may show a net decline under the corresponding period of last year of more than 147,000,000 bbl. This, it is shown, would be a decline under last year of 40.2 percent.

The Gasoline Market

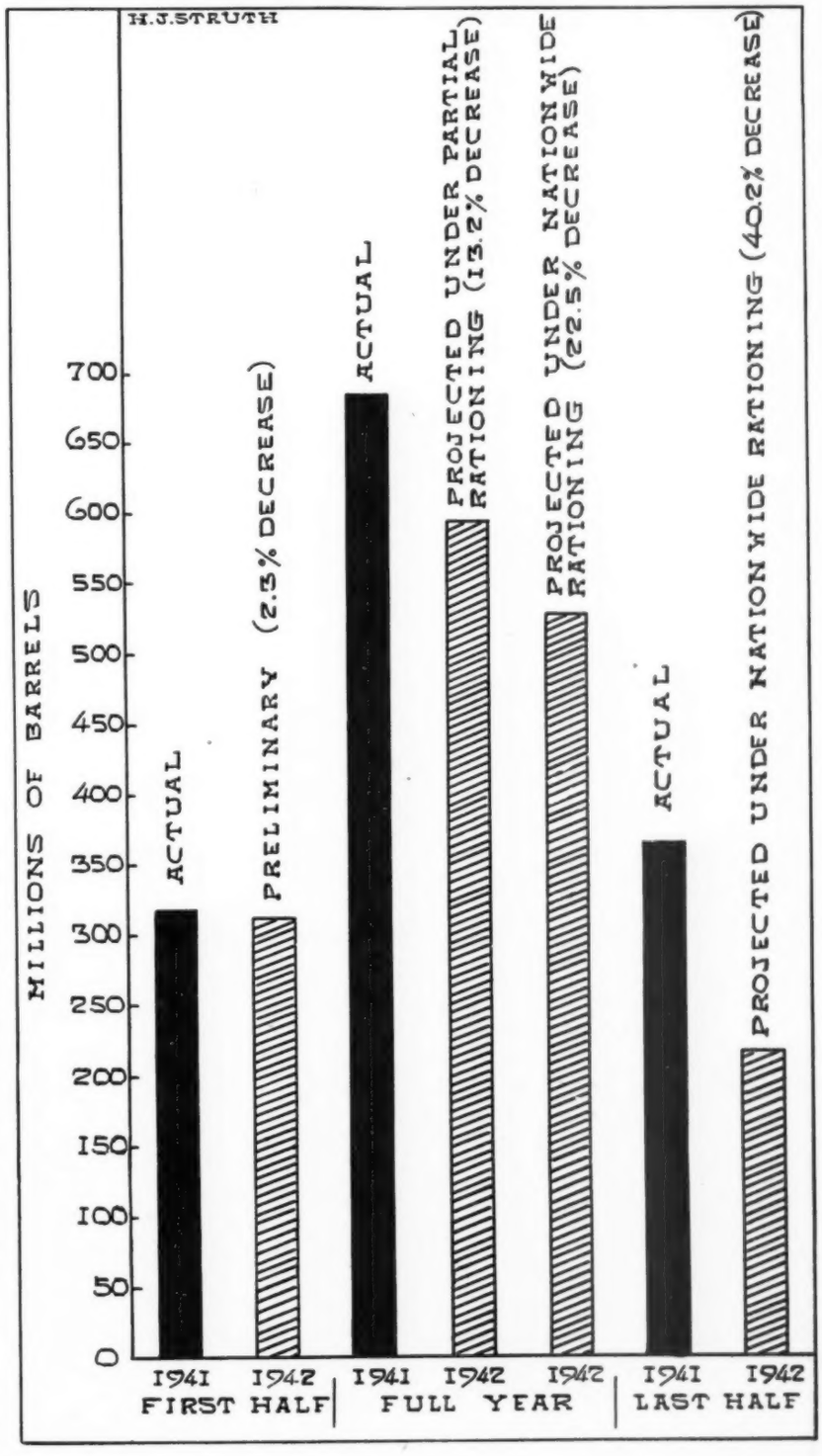
Although the conservation of rubber is undoubtedly an important consideration in the proposal to extend gasoline rationing to a nationwide basis, another consideration of perhaps even more importance is the ultimate effect of severely reduced markets for motor fuel upon the oil industry's present and projected war production program. The production of motor fuel for civilian use is part and parcel of the refining processes that are the all - important source of aviation gasoline for military requirements. Even though refinery schedules have been adjusted to produce less motor fuel per bbl. of crude oil processed, the fact remains that any further disruption in already curtailed markets for motor fuel must result in heavy storage accumulations. If nationwide rationing is adopted and results in the loss of more than 147,000,000 bbl. in motor fuel consumption during the last half of this year, that quantity of motor fuel would necessarily have to be added to the more than 86,000,000 bbl. in storage on June 30. This would build the industry's stored supply of gasoline to 233,000,000 bbl. Such an accumulation of gasoline would be far beyond existing storage facilities and would, in the final analysis, force refineries now producing highly necessary war products to shut down for lack of tankage.

Oil Reserves per Well

Fig. 6 shows the national distribution of oil reserves on a per well basis. Although Texas has well over half of the nation's proved oil reserves, the total credited to this state must be divided between more than 100,000 producing wells, making the average reserve per well 108,700 bbl. Louisiana, Mississippi, and California, in the order named, led

Fig. 5. Probable effect of rationing upon gasoline consumption

First two columns show actual gasoline demand for all purposes in first half of 1941 and 1942. Next three columns indicate probable course of gasoline consumption under partial or existing rationing in Eastern States and under nationwide rationing of all states in comparison with actual consumption last year. Last two columns show probable effect of nationwide rationing upon gasoline consumption in last half of this year compared with corresponding period of last year. Details are shown in Table 8



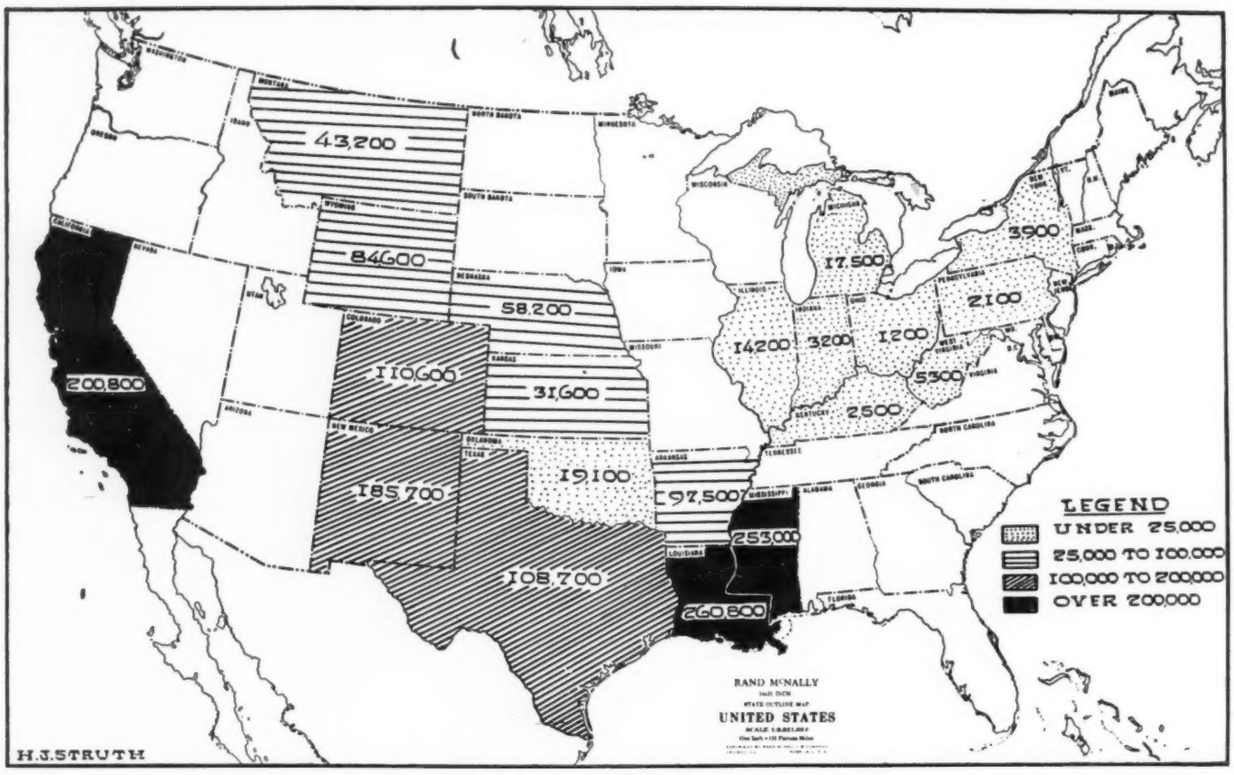


Fig. 6. Reserves per well of principal oil states

Figures shown in each state represent number of bbl. of reserves per producing well as of January 1, 1942. Shading emphasizes areas of major and minor importance as indicated by legend. Details of reserves, wells, and other vital data shown in Table 9

all other states in reserves per well of more than 200,000 bbl. Texas, New Mexico, and Colorado are classed between 100,000 and 200,000 bbl. per well. Montana, Wyoming, Nebraska, Kansas, and Arkansas have reserves of from 25,000 to 100,000 bbl. per well. The other oil producing states, including Oklahoma, have reserves of less than 25,000 bbl. per well.

An important consideration with respect to reserves per well is the rate at which wells are produced. In Mississippi, for example, where known reserves constitute a supply of 253,000 bbl. per well, the rate of production last year was 48,300 bbl. per well. At this rate, the reserve supply of Mississippi would last but five years. On the other hand, Texas has 108,700 bbl. per well but produced last year only 5,000 bbl. per well. At this rate, Texas' reserve supply presumably would last nearly 22 years.

National Oil Reserves

In measuring known underground reserves in terms of future supply, it is decidedly necessary to include in such calculations the continued discovery of

TABLE 9

Summary of wells, reserves, new discoveries, and production—1941-42

State	Number of producing wells, Jan. 1, 1942	Total reserves Jan. 1, 1942	Reserves per well	New reserves discovered*	Dry holes drilled	Reserves discovered per dry hole	1941 oil production	1941 production per well
Arkansas	3,027	295,017,000	97,500	9,535,000	83	114,900	26,327,000	8,700
California	16,547	3,323,147,000	200,800	18,750,000	178	105,300	230,263,000	13,900
Colorado	212	23,443,000	110,600	....	12	....	1,875,000	8,800
Illinois	23,411	333,714,000	14,200	62,946,000	913	68,900	134,138,000	5,700
Indiana	7,079	22,873,000	3,200	1,926,000	203	9,500	6,634,000	900
Kansas	21,838	689,795,000	31,600	23,673,000	597	39,700	83,261,000	3,800
Kentucky	14,504	36,450,000	2,500	213,000	218	1,000	4,762,000	325
Louisiana	5,100	1,330,134,000	260,800	47,915,000	470	101,900	115,908,000	22,700
Michigan	3,173	55,620,000	17,500	27,330,000	421	64,900	16,361,000	5,200
Mississippi	317	80,207,000	253,000	1,000,000	59	16,900	15,314,000	48,300
Montana	1,995	86,124,000	43,200	....	52	....	7,526,000	3,800
Nebraska	69	4,014,000	58,200	1,550,000	49	31,600	159,000	2,300
New Mexico	3,633	674,817,000	185,700	1,201,000	52	23,100	39,369,000	10,800
New York	15,227	59,816,000	3,900	....	1	....	5,185,000	340
Ohio	31,127	37,404,000	1,200	3,660,000	502	7,300	3,340,000	100
Oklahoma	54,147	1,035,820,000	19,100	58,911,000	697	84,500	154,759,000	2,900
Pennsylvania	82,980	170,897,000	2,100	....	130	....	16,750,000	200
Texas	100,975	10,975,641,000	108,700	170,364,000	2,275	74,900	507,584,000	5,000
West Virginia	9,462	50,011,000	5,300	1,000,000	138	7,200	3,433,000	360
Wyoming	3,595	304,053,000	84,600	....	34	....	29,694,000	8,300
Other States	200	299,000	1,500	....	37	....	1,540,000	†
U. S. total	393,616	19,589,296,000	49,800	429,974,000	7,121	60,400	1,404,182,000	3,600

*—Does not include extensions and revisions that are credited to years of original discovery.

†—Not available on a comparable basis.

new sources of supply. Although our national proved reserves of oil presumably constitute about 14 years' supply at current rates of production, they would in reality be produced over a period of perhaps 30 or 40 years if no new sources of supply were discovered —but not at present rates of production. A study of well production decline curves proves conclusively that our present production rates would be comparatively short-lived if oil operators were to cease all efforts to find new sources of supply.

It is for this reason that the facts concerning the alarming rise in dry-hole ratio, previously discussed herein, become an all-important consideration in the oil industry's immediate development program. If the rate of discovery continues downward for any length of time, we may suddenly realize that the nation's oil wells may not be able to make their allowable rates of production.

Under existing drilling restrictions, brought about by the establishment of priorities, the national reserve picture is far from satisfactory. If, as has been previously pointed out, we drill less than 16,000 wells this year, the number of dry holes will probably amount to 5200. Table 10 shows that we discovered about 60,400 bbl. of new supply, excluding extensions and revisions, for each dry hole drilled last year. If this same rate of discovery continues this year it is likely that the industry will only find about 300,000,000 bbl. of distinctly new reserve supply in 1942. However, as this year's drilling effort is being confined largely to unproved areas (primarily wildcat operations), the rate of discovery per dry hole drilled may be reduced to but 200,000,000 bbl. of new reserve supply.

Decrease of National Reserves

Last year, the national reserves of oil were increased by nearly 2,000,000,000 bbl., but 1,500,000,000 bbl. of that was accounted for by extensions and revisions to previously discovered oil pools. Under existing restrictions, due to unavailability of materials, it is likely that extension work will have been drastically curtailed with the probable result that new reserves added by extensions to existing pools will be halved. It is entirely likely, therefore, that the total additions to proved reserves this year will not exceed 1,000,000,000 bbl. This would not only cause a net reduction in proved reserves this year but may also result in a generally lower national average ability to produce from existing wells.

Fig. 7 reveals the effect of declining new reserve discoveries upon the cost of finding oil. These data are based on figures shown in Table 10. In 1935, the industry drilled 4311 dry holes at an average cost of about $18,000 per hole. In that year new reserves discovered,

Fig. 7. Trend of new reserve discoveries and cost of finding oil

The sharp decline in new oil discoveries since 1935 has greatly increased the cost of finding new sources of supply. Projections through 1942 are based upon a reduction in drilling to about 15,000 wells this year and the possible discovery of between 200 and 300 million barrels of new reserves. Depending upon the outcome of this year's drilling, the cost of finding a million barrels of new supply may range from $346,000 to as much as $520,000. Details of data upon which this chart is based are shown in Table 10

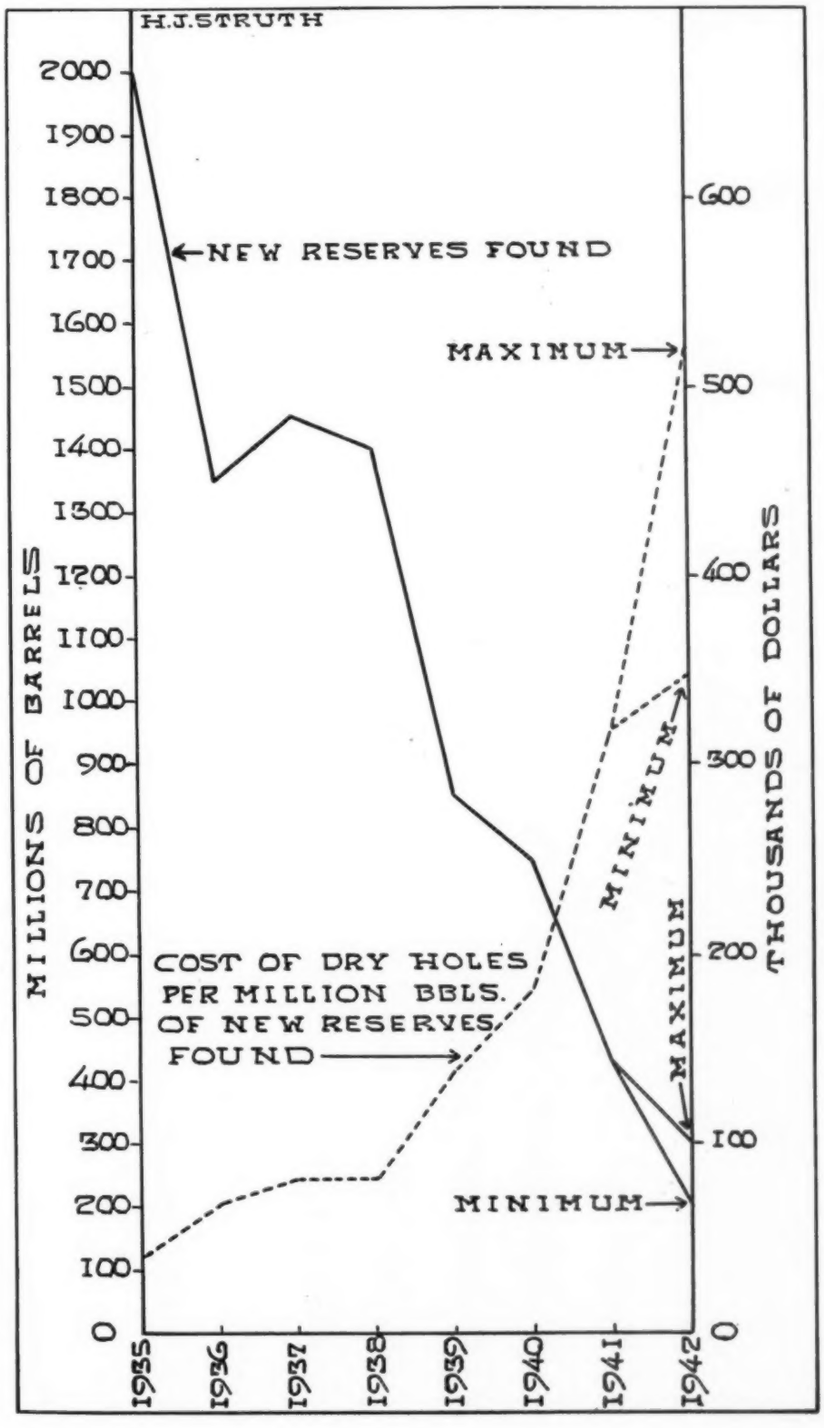


TABLE 10

Cost of finding oil in United States

Year	Dry holes drilled	New oil reserves found* bbl.	Dry holes per 1,000,000 bbl. of new reserves	Approximate cost of dry hole per 1,000,000 bbl. of new oil found
1935	4,911	2,000,000,000	2.5	$ 43,250
1936	5,296	1,350,000,000	3.9	68,250
1937	6,420	1,450,000,000	4.4	79,200
1938	6,043	1,400,000,000	4.3	79,550
1939	6,357	850,000,000	7.5	142,500
1940	6,617	750,000,000	8.8	171,600
1941	6,848	430,000,000	16.0	318,000
1942 (a)	5,200	Min. 200,000,000	26.0	520,000
		Max. 300,000,000	17.3	346,000

*Extensions and revisions credited to years of original discovery.

(a) Projected on basis of restricted drilling, assuming the possibility that about 5200 dry holes will be drilled this year and a maximum of 60,000 bbl. of new supply found for each dry hole drilled. The minimum reserve addition is based upon the likelihood of finding only about 40,000 bbl. per dry hole.

exclusive of extensions and revisions, totaled about 2,000,000,000 bbl. This meant that 2½ dry holes were drilled for each 1,000,000 bbl. of new supply discovered. The cost of finding oil in 1935 was about $43,250. By contrast, in 1941, the industry drilled 6848 dry holes and only found 430,000,000 bbl. of new supply. The cost of finding this oil was about $318,400 per 1,000,000 bbl.

Conclusion

If the industry drills 5200 dry holes this year and finds a maximum new reserve supply of 300,000,000 bbl., it will take 17.3 dry holes for each 1,000,000 bbl. of new supply and it will cost about $346,000 per 1,000,000 bbl. On the other hand, if these 5200 dry holes result in the discovery of only 200,000,000 bbl. of new oil supply, it may take 26 dry holes per 1,000,000 bbl. and the cost may rise to $520,000 per 1,000,000 bbl. of new supply discovered. This is a decidedly alarming situation and one that commands serious thought on the part of the industry and our government officials in Washington. The search for new sources of oil supply is fundamental to the future welfare of the petroleum industry and the nation, even though present reserves may be considered adequate for immediate needs.

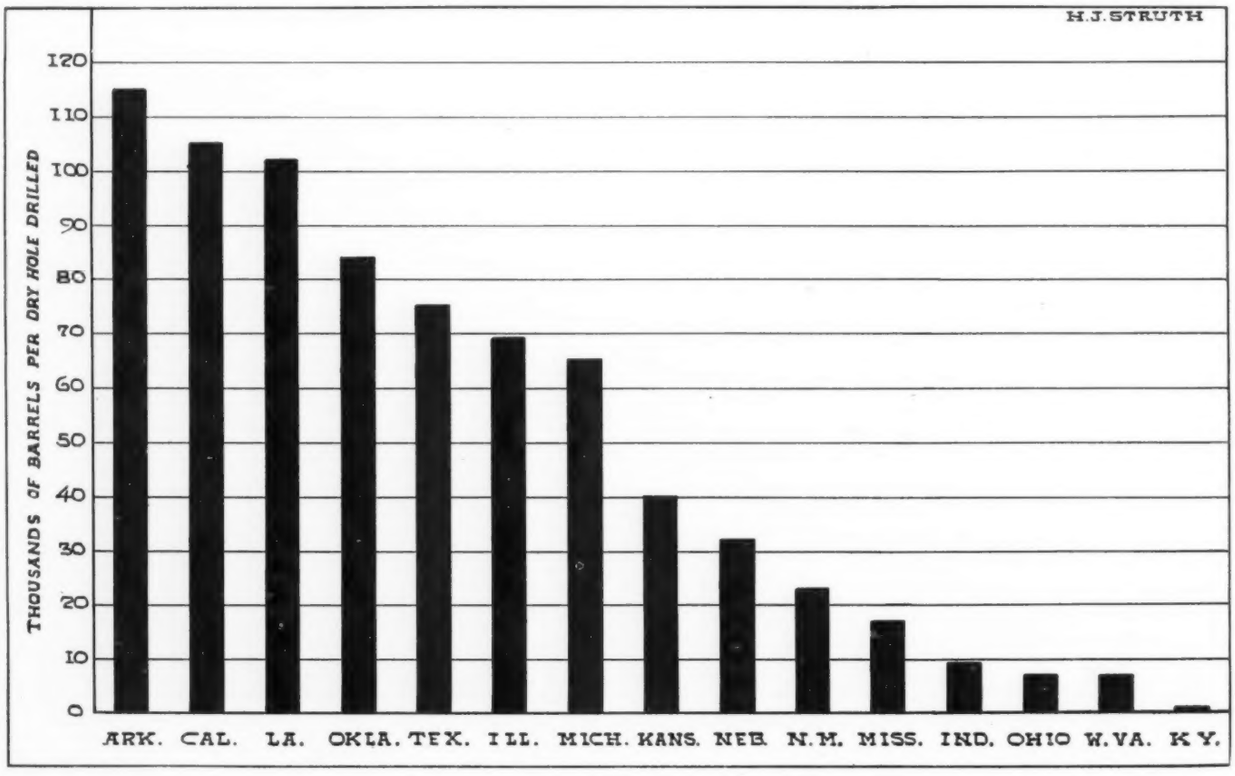
The degree of success attending efforts to find new sources of oil supply may be measured by the average quantity of new oil discovered per dry hole drilled. Fig. 8 classifies the various oil producing states in accordance with rates of discovery per dry hole drilled in 1941. The data supporting this chart are contained in Table 9, showing reserves, wells, dry holes drilled, rates of discovery, and production data for 1941.

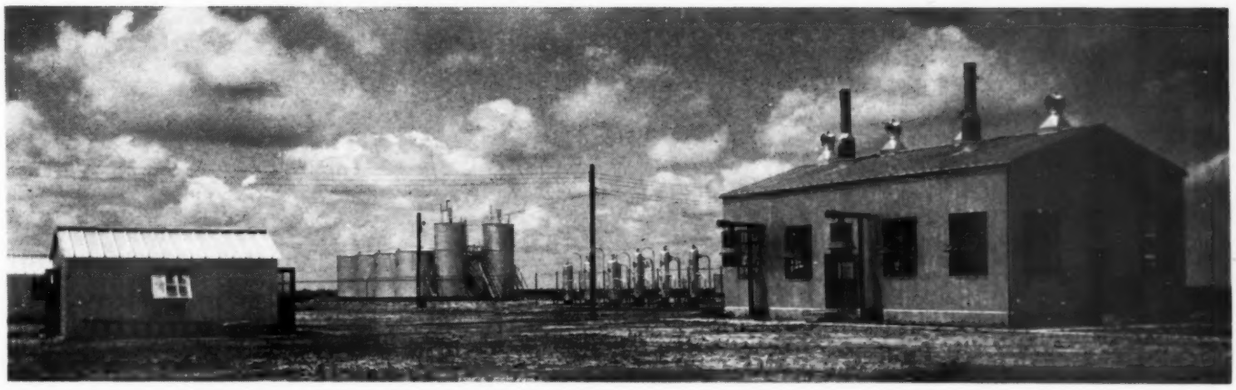
Arkansas held first place with the discovery of 114,900 bbl. of oil for each dry hole drilled. Arkansas, California, and Louisiana, in the order named, led the nation with an average discovery per dry hole drilled of 104,000 bbl. Oklahoma, Texas, Illinois, and Michigan found an average of 74,000 bbl. of new oil per dry hole drilled. The rest of the oil states discovered from 1000 bbl. to 39,700 bbl. of new supply per dry hole drilled.

—— ☆ ☆ ☆ ——

Fig. 8. New oil reserves discovered per dry hole drilled

The degree of success in finding oil in the various producing states is shown by comparing the average quantity of new reserves found per dry hole drilled. Details upon which these data are based are shown in Table 9





General view of cycling plant in Joyce Richardson field, Harris County, Texas

Simplified Method of Processing Characterizes Cycling Plant

PETROLEUM ENGINEER Exclusive Feature

☆ **Series of oilfield-type separators used to extract condensate—Residue gas returned to producing formation**

by Frank H. Love
Managing Editor

A SIMPLIFIED method of handling production from high-pressure condensate wells for removal of gasoline content and for pressure-maintenance purposes is demonstrated by the unusual design of the recently constructed cycling plant in the Joyce Richardson field, Harris County, Texas, installed by Christian-Carpenter Drilling Company, Joyce Richardson et al. The pressure-maintenance and cycling program was made possible by a unitization plan agreed upon by operators in this comparatively new field, approximately 2000 acres being included in the program. In addition to the condensate wells there are several oil-producing wells included in the unitization plan.

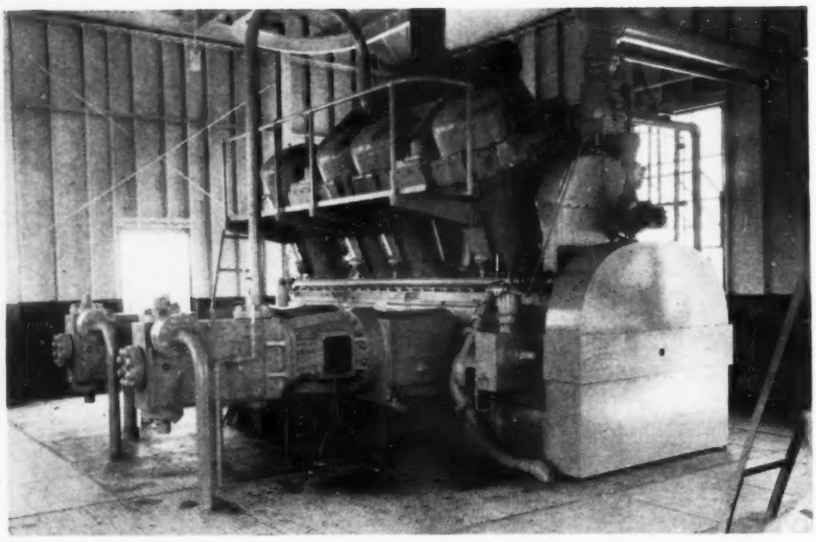
In designing the plant the scarcity of materials was a factor of vital consideration and did not permit the installation of absorption equipment. The gas is processed by means of a series of oilfield-type separators designed and operated to produce a 52-57-gravity product. According to Saybolt analysis, this simplified processing fails to recover only about ½ gal. of condensate per M. cu. ft. of gas. As the gas containing this condensate is returned to the producing formation, it is not considered lost for eventually it will be recovered when absorption equipment is added to the plant at some later date. Provision has been made for the future installation of additional equipment with a minimum of expense and difficulty.

Production of the plant is about 280 bbl. of condensate a day from four gas wells producing from the Yegua formation at a depth of 6900 ft. Two oil wells also are connected to the plant and the gas produced with the oil is being sent through the compressors and returned to the producing formation along with gas from the condensate wells. The gas produced with the oil is not being stripped of its gasoline content, however. The pressure-maintenance program is so designed to permit processing of the wet gas injected at a future period when sufficient equipment is obtainable. Returning the gas to the sand permits production of the oil wells in the field, previously impossible because of the loss of reservoir gas pressure. Oil and gas separation from the oil wells is accomplished by an individual series of separators and gun-barrel separation employed to remove any water before the crude oil passes to storage tanks.

Wellhead pressure of the condensate wells is 2500 lb. and the gas is brought to the plant through 2½-in. individual lines where it enters a common 4-in. header arranged with meter settings, adjustable choke valves, and temperature gauges. Provision also is made at this manifold to bypass any well into a test separator and tank when desired for the purpose of checking production of that particular well. The adjustable chokes reduce the pressure to 1000 lb. The gas stream is split and passes to three primary separators, which have an operating range of 800 to 1000 lb., but at present are being operated at 1000 lb. Condensate is removed and is then staged through a series of three separators. The first-stage separator reduces the pressure to 435 lb., the second-stage to 125 lb., and the final-stage to 30 lb. The resulting 52-57-gravity product is discharged to storage tanks, consisting of four 500-bbl. vessels. Trucks are used to transport the final product from the plant storage tanks to various refineries for further processing and blending.

Residue Gas Cycle

Gas from the three primary separators enters a common header and then passes through a scrubber before entering the suction header of the compressors. The two 650-hp., V-angle type compressors receive the gas at a suction pressure of 1000 lb. and discharge to the injection well at a pressure of 2900 lb. A galvanized sheet metal building 28 ft. by 52 ft. houses the two compressors. Each compressor is equipped with two cylinders of 4½-in. bore and 15-in. stroke.



One of the two 650-hp., V-angle compressors that compress the gas from 1000 lb. to 2900 lb. for injection

The injection line is of 4-in. diameter, the pipe having 0.631 in. wall thickness. Gas is injected into both the tubing and casing of the injection well. Input gas is metered twice, once between the scrubber and intake of the compressors, and the second time immediately after leaving the compressor discharge header.

The entire gas throughput of the plant, except for a limited amount used as a fuel, is utilized for pressure maintenance; this varies from 22,000,000 to 27,000,000 cu. ft. per day, although the plant is designed for a total capacity of 30,000,000 cu. ft. per day.

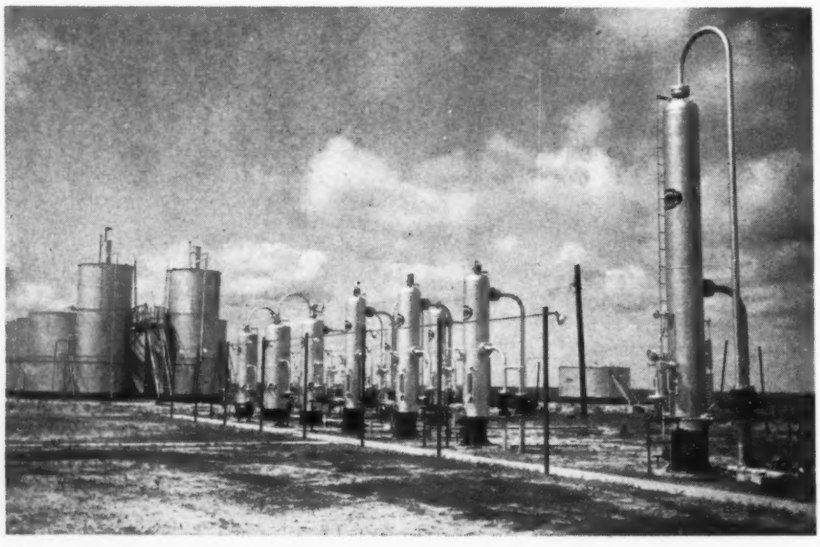
Fuel gas for the compressor engines is taken from the line at a point between the scrubber and engines, being passed through a series of regulators that reduces the pressure from 1000 lb. to 2 oz. This final reduction is immediately ahead of two surge tanks from which the fuel gas enters the mixing valves of the engines.

Engine jackets are cooled by water circulating in a closed system, the water flowing from a 100-bbl. surge tank to the engine jackets, thence through the cooling coils, and back to the surge tank.

A raw water system is employed to cool the engine lubricating oil and compressor cylinders. The system consists of two concrete, steel-reinforced pits each 110 ft. by 110 ft. by 8 ft. deep. One pit serves as the suction pit, from which cooling water is pumped, and the remaining pit as the return or hot water pit. The suction pit is supplied with water from a well 170 ft. deep. Water is pumped from this pit by a motor-driven centrifugal pump through an 8-in. line to the engines. The returning hot water is discharged into the hot water pit. The two pits are connected through the base by a 10-in. diameter concrete pipe. This arrangement makes it necessary for the hot water entering the suction pit from the hot water pit to pass upward through the cool water, resulting in more effective cooling.

Provision has been made to prevent lines from freezing in the wintertime. For this purpose a 125-hp. oilfield type boiler has been installed. All lines likely to freeze, such as those to the metering manifold and to the primary separators. are steam-jacketed to maintain a temperature of 70°F.

Scrubber (foreground), separators (center), and storage tanks (background)



Safety Equipment

Safety equipment assures the plant of automatic shut-down in case of trouble. Two pressure-reducing regulators have been placed on the 4-in. line between the meter runs and the three primary separators. Use of these regulators allows the operator to maintain 1000 to 1100 lb. pressure on the separators, but should an emergency occur resulting in either an increase or decrease in pressure, the regulators shut-off the flow of incoming gas before it reaches the separators. A safety regulator also has been installed on the vent line connecting with the main line between the scrubber and the compressor cylinders and is adjusted to release the gas when the pressure exceeds 1000 lb. This is an important safety feature as protection to plant equipment and personnel is assured should one of the engines be shut down, or either or both engines slow down from overload. In such event the gas is vented and the pressure relieved without the necessity of manual operation.

Producing and Input Wells

The four gas-condensate wells are producing from the Yegua sand at a depth of 6900 ft., as previously mentioned, whereas one oil well is producing from a depth of 6650 ft. and another from a depth of 6400 ft. In the producing wells casing was set and cemented through all producing zones and the 6900-ft. zone perforated with 24 shots. The input well was completed in the 6900-ft. sand and 5-in. diameter, 15-lb. casing set and cemented, after which it was perforated with 100 shots and the formation acidized with 2000 gal. of acid.

THRIFTEASE by a Silent Scot

"Silent Scot" is a little valve that insures quiet, economical performance in the fuel injection system of the type G-MV Compressor.

This valve has a unique port which vents gas directly toward the spark plug and into the flow of combustion air, to provide an economical, instantly combustible fuel mixture that fires under any load. Simply turning the valve head with a wrench increases or decreases the size of the port opening and adjusts gas flow for BTU content, or to balance load between cylinders. Clearance between valve stem and tappet is never changed, thus assuring silent operation and minimum wear.

Fuel economy and quietness due to "Silent Scot" are two more advantages which G-MV owners can credit to Cooper-Bessemer's expert engineering and precision manufacture.

TYPE G·MV ANGLE COMPRESSOR

THE COOPER-BESSEMER CORPORATION
MOUNT VERNON, OHIO
Plants: Mount Vernon, Ohio and Grove City, Pa.
New York City Washington, D. C. Shreveport Dallas Houston
Tulsa St. Louis Los Angeles Greggton, Texas Pampa, Texas

by Cooper - Bessemer

ENGINE BUILDERS SINCE 1833...

Gravel Pre-Packed Liners

PETROLEUM ENGINEER Exclusive Feature

☆ An outline of the methods developed for installing, using, and washing this useful device

by F. A. Graser
Consulting Petroleum Engineer

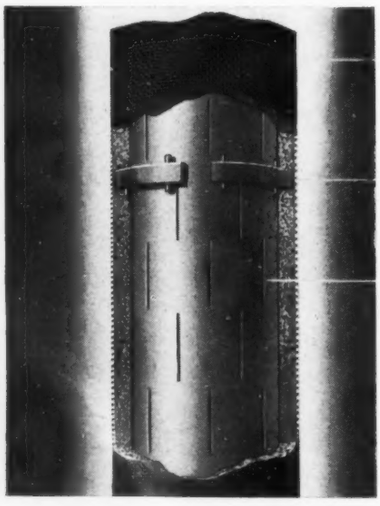
GRAVEL pre-packed liners and the methods employed in cleaning them are developments over a period of time rather than new ideas being thrust upon the oil industry. The idea of gravel-packing developed from the use of gravel in water wells and the study of the screening effect of the larger sizes of gravel upon the smaller sizes. The additional surface of a larger bore also was considered an advantage for the purpose of increasing the gravity flow of oil into the well. It might be desirable to review briefly some of the developments in the California oil fields, about which the writer is familiar and which have led to the present pre-packed liner and its method of cleaning.

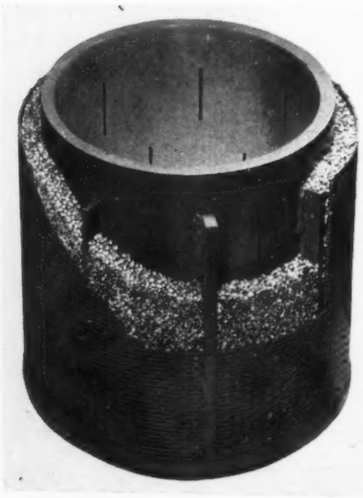
Eighteen years ago the relationship of the size of sand grains that could be screened by a slot was established whereby it was determined that sand grains would not pass through a slot if the diameter of the grain was greater than one-half the width of the slot. At the same time it was found that if there was a mixture of different sand grains with one-seventh of a larger size, then this larger size sand would form a bridge over the slot opening and screen-out the finer sand. Later work along this line in a separate investigation developed the fact that this percentage could be as small as one-tenth of the volume in order to screen effectively the balance of the sand. As the result of these early experiments the idea of enlarging the bore of the hole was expounded, but at that time there was no practicable way of enlarging the size of the hole a sufficient amount to allow the introduction of gravel. As time went on the wall scraper was developed with which the size of the hole could be increased by several inches beyond the size that could be drilled through the water string. Then it could be seen that it might be practicable to introduce gravel between the perforated liner and the wall of the hole. In this manner the finer sands could be screened with a reduction in the amount of sand produced through

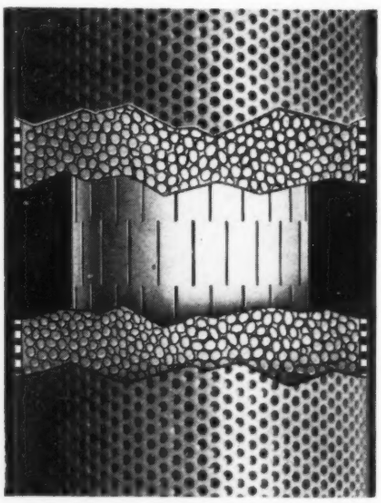
F. A. GRASER

graduated from University of California with a B.S. degree, having majored in petroleum engineering in the College of Mining—He interrupted his college work to enter the field artillery and served 10 months in France and 8 months in Germany with the Army of Occupation during the First World War—After graduation he worked for the California State Division of Oil and Gas—In 1928 he was petroleum engineer for Petroleum Securities Company—Then spent a few months in the California Oil Umpire's office before going with the Southern California Drilling Company as field superintendent—In 1931 he opened an office as consulting petroleum engineer specializing in development work and has been in consulting work since.

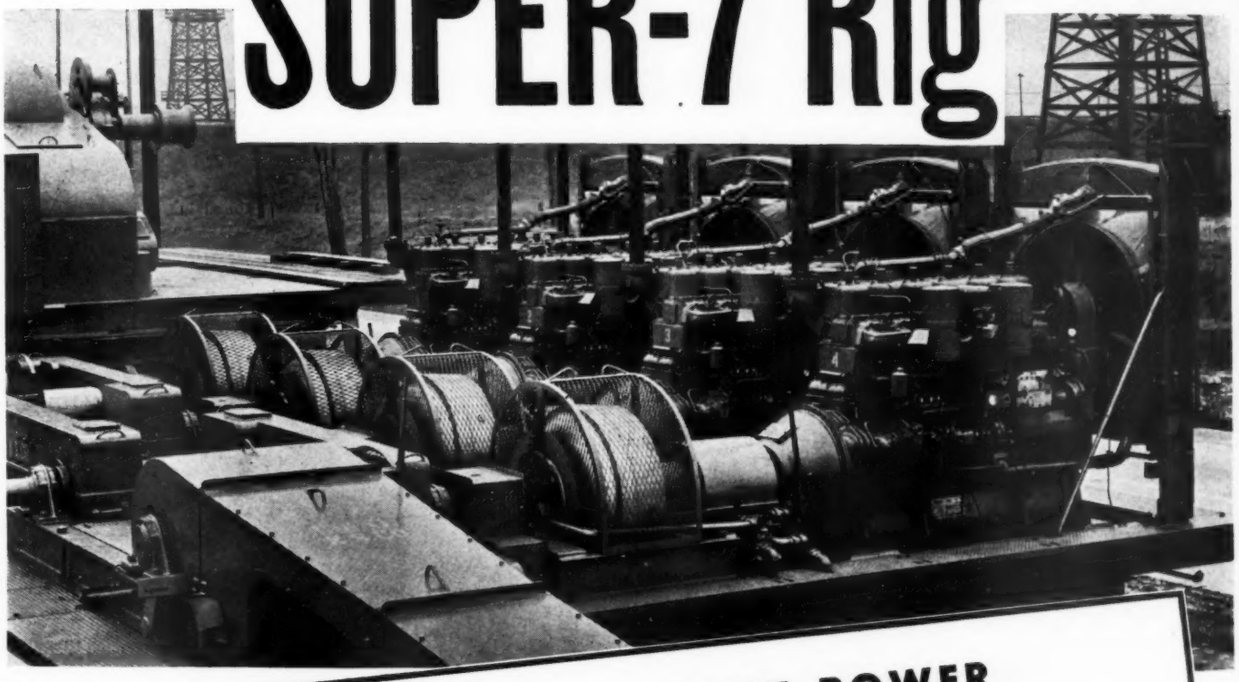
Fig. 1. Three types of pre-packed liners. The one to the left is the wire screen type. The one in the center is made with horizontal slots punched in the outer covering and is reinforced with vertical ribs. The one to the right is made with holes punched in the plate





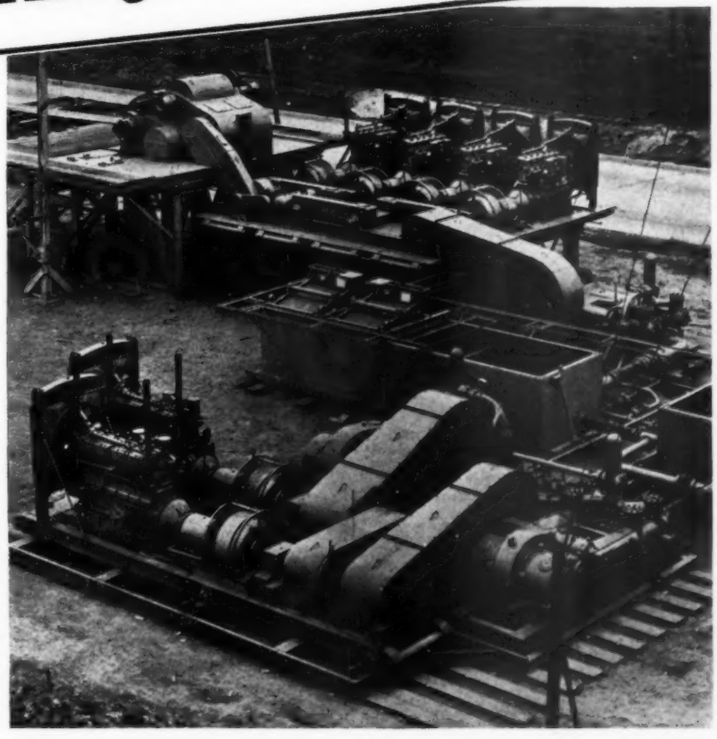


SUPER-7 Rig



POWERED BY 7 GIANT POWER

WAUKESHA HESSELMAN *Oil* ENGINES



Destined for use in far-distant foreign oil fields, this super-modern drilling rig will push production to new peaks in the cause of the United Nations.

Built by the National Supply Company, the huge rig is owned by the Superior Oil Co.

Look at its tremendous power plant—seven Model LRHU Waukesha-Hesselman Oil Engines, each 2894 cu. in. displacement. Picture at the right shows six of them—the seventh is used as an auxiliary mud pump mixing engine.

In addition to these seven, there are four Waukesha Engines for auxiliary power—three 4-cyl. units of approximately 50 hp. each, and one 6-cyl. unit of approximately 125 hp.

Note particularly that they're all Hesselman Oil Engines—easy starting, low pressure, electric ignition engines—burning easy-to-get furnace oils, as well as high-speed diesel fuels, with the *greatest overall economy*. Get Bulletin 1116.

WAUKESHA MOTOR COMPANY
WAUKESHA, WISCONSIN
NEW YORK • TULSA • LOS ANGELES

PETROLEUM ENGINEERING EDITION

BAASH-ROSS News

THE BAASH-ROSS TOOL COMPANY, LOS ANGELES, HOUSTON, NEW YORK

A BULLETIN COVERING NEWS OF EQUIPMENT AND OPERATIONS IN THE PETROLEUM INDUSTRY

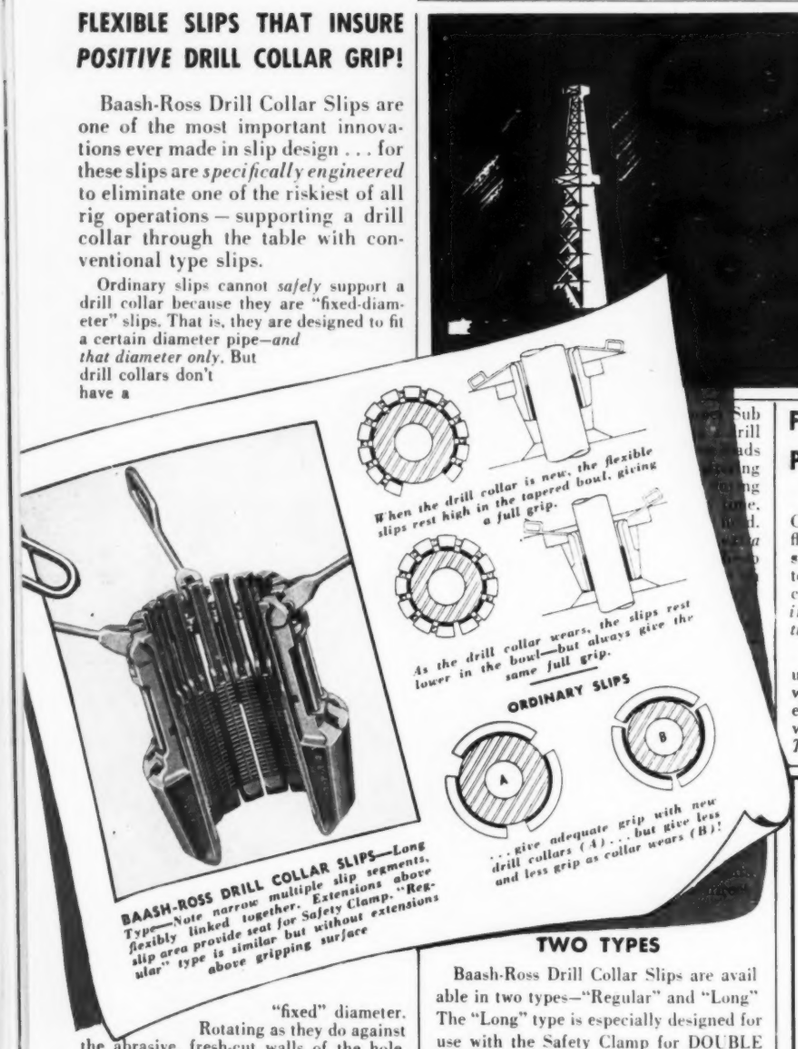
NOW MORE THAN EVER

These two safety developments are vital to your rig operations

FLEXIBLE SLIPS THAT INSURE *POSITIVE* DRILL COLLAR GRIP!

Baash-Ross Drill Collar Slips are one of the most important innovations ever made in slip design . . . for these slips are *specifically engineered* to eliminate one of the riskiest of all rig operations — supporting a drill collar through the table with conventional type slips.

Ordinary slips cannot *safely* support a drill collar because they are "fixed-diameter" slips. That is, they are designed to fit a certain diameter pipe—*and that diameter only*. But drill collars don't have a "fixed" diameter.


When the drill collar is new, the flexible slips rest high in the tapered bowl, giving a full grip.
As the drill collar wears, the slips rest lower in the bowl—but always give the same full grip.
ORDINARY SLIPS
A
B
. . . give adequate grip with new drill collars (A) . . . but give less and less grip as collar wears (B)!

BAASH-ROSS DRILL COLLAR SLIPS—Long Type—Note narrow multiple slip segments, flexibly linked together. Extensions above slip area provide seat for Safety Clamp. "Regular" type is similar but without extensions above gripping surface

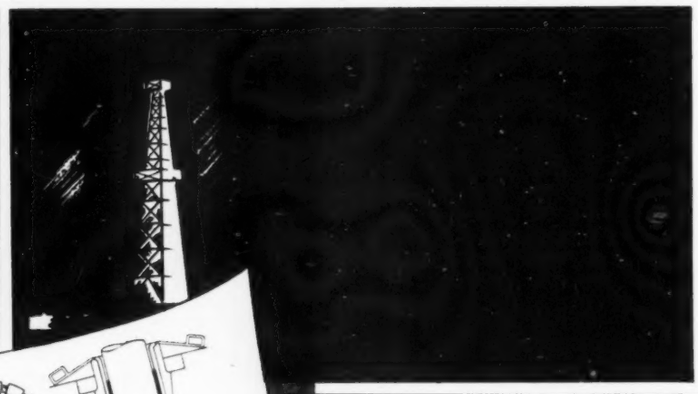
Rotating as they do against the abrasive, fresh-cut walls of the hole, they lose diameter rapidly—become not only smaller but often out-of-round, as well. Ordinary "fixed-diameter" slips cannot compensate for this wear (see sketch) —consequently, they grip the collar less and less securely, with a steadily increasing risk of dropping it down the hole.

Now look at the Baash-Ross Drill Collar Slip. It's made up of narrow segments, *flexibly hinged together*. It w-r-a-p-s around the collar like a chain tong—fits *every inch* of the circumference whether the collar is new, worn, round, or out-of-round. It's a grip that won't slip on even the hardest-to-hold collars!

TWO TYPES

Baash-Ross Drill Collar Slips are available in two types—"Regular" and "Long" The "Long" type is especially designed for use with the Safety Clamp for DOUBLE protection . . . has extensions above the slip surface to provide a seat for the Clamp. Both types have interchangeable liners for long life, low maintenance.

Your investment in a set of these Slips will protect you for years—*there's practically no wear-out to them.* And they're available in sizes to fit all diameters from 3¾" to 8¼". Your nearest Baash-Ross representative has complete details. Why not call him today? Or write for Bulletin 13!



FULL-GRIP SAFETY CLAMP

Protects Flush Joint Equipment

Once you've used this Baash-Ross Safety Clamp, you'll never handle any kind of flush joint equipment without the positive safety it affords. On and off in a jiffy, this tool takes an instant grip on *any* cylindrical surface, round or out-of-round . . . *and increased load only cinches the grip tighter!*

HERE'S ALL YOU DO: The Clamp is unusually simple and quick to use. Simply wrap it around the pipe above the slips or elevator, drop a pin in place and tighten with a quick cinch of the socket wrench. *That's all there is to it.* Each individual link in the Clamp has an independent gripper wedge that takes a firm initial hold on the pipe surface. As the load increases—or should sudden impact loading occur—the tapered slips wedge themselves even tighter, forming a grip that holds the heaviest loads without slipping. And because the grip is uniformly distributed at *all points*, it will not crush even thin-walled pipe!

Another point—links can be quickly added or removed *on the rig* so that the Clamp can be quickly adapted to fit *any* diameter from 3¾" up. A neat steel case is provided for storing the extra links, as well as the Clamp and wrench, when they're not in use.

MANY USES

Judging by reports, the Safety Clamp is one of the most versatile tools ever put into the fields. Besides safeguarding against dropping flush joint equipment in normal rig operations, operators report finding it ideal as an elevator shoulder when handling prepacked gravel liners. Another reports using it as an emergency shoulder on fishing jobs, lifting as much as 4000′ of 4½" drill pipe with it—*safely!*

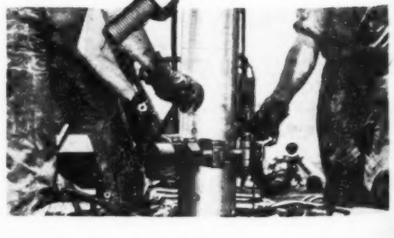
You need this tool around your rig —for safety, for efficiency, for protecting your hard-to-get drill strings. It's low in cost, and it will last for years with practically no maintenance. Your nearest Baash-Ross representative will be glad to show it to you . . . or write direct for Bulletin 6 giving complete information!

Multiple Grip!

Each separate link in the Safety Clamp carries an independent slip-type gripping member. Wedging action tightens grip as load increases.

Quick Protection!

Simply wrap the Clamp around the pipe, drop a pin in place and cinch the nut tight with a quick-acting wrench. On or off in an instant . . . yet once applied, will not slip under heaviest loads!



the well, a reduction in operating expense, and a lessening of the need to redrill due to shifting formations that cause the liners to collapse or become crooked.

The short string of less than 100 linear ft. did not offer great difficulties in introducing the gravel between the liner and the wall of the hole. The circulation system for conventional packing consists of the drill pipe, the water string, the perforated liner at the bottom of an underreamed hole extending upward into the water string, and a tail piece attached to the bottom of the drill pipe extending downward to the bottom of the liner. The tail piece had a number of swab rubbers facing upward to keep the flow of circulating fluid from the liner or else a close fit to the liner to allow a fluid seal. The circulating fluid carried the gravel down the well between the drill pipe and water string then back of the liner to the bottom of the hole. The circulating fluid returned through the tail piece and drill pipe screening the gravel and leaving it around the liner. As the length of the liners increased, it became necessary to pull back the drill pipe and tail piece periodically in order to keep the circulating pressure at a low level. In this manner several hundred feet of liner could be packed with gravel. Because of the danger of settling, it was found necessary to build up a reservoir of gravel. This was accomplished by extending the top of the liner for a considerable distance up into the water string and filling the space to the top of the liner. Lead seal drive-down adaptors held the gravel in place.

In the Wilmington field, Los Angeles County, California, the first wells to be packed with gravel used ¼-in. gravel and a sheath of gravel 5 in. or more thick. Later, finer gravels were used in that field. Wilmington comparisons are made because the pre-packed liner had its greatest development in that field.

There were several disadvantages in the use of long conventional gravel-packed liners, but despite the disadvantages and difficulties of conventional gravel-packing, there is no doubt that the conventional gravel-pack was a definite contribution to the oil industry and is here to stay.

Pre-Packed Liners

Under conditions where the conventional gravel-pack could not be used, operators began consideration of a substitute. It was reasoned that if the size of the gravel were reduced and held in position over the perforated casing, then a thick pack would not be necessary. The size of the hole could also be reduced, cutting drilling costs. Most of the first pre-packed liners were more or less experimental and represented attempts by operators to overcome production problems.

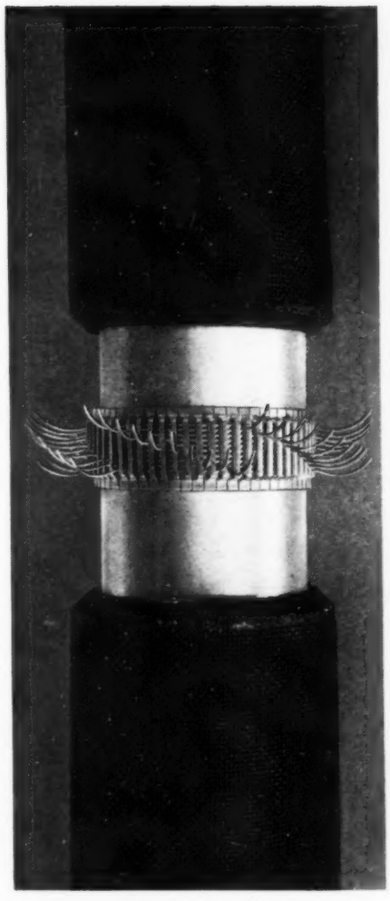


Fig. 2. The wall-cleaning guide or "scratcher" is shown mounted between pre-packed sections of a liner

The first gravel pre-packed liner of which there is a record was used in a well in the Dominion area of Kern County on October 21, 1937. Conventional liners were unsuccessful because of the fine silty unconsolidated condition of the oil sand. A conventional gravel-pack was attempted but the liner was so short that it pulled out of the gravel with the tail piece because of the frictional resistance of the swab rubbers. As a result 21 ft. of 4½-in. O. D. perforated drill pipe was packed with 6-7 gravel (see Table I) held in position by a 7⅝-in. O. D. ⅛-in. mesh galvanized screen. Seventeen feet of 5¾-in. blank casing on top of the 4½-in. drill pipe filled out the liner. The pre-packed liner was not particularly successful and was later pulled. An examination showed that the gravel was plugged with dry silt, thereby shutting off the flow of oil into the well.

TABLE I

No.	Sieve sizes, approx. in.	U. S. Standard (microns)
4	0.185	4760
6	0.137	3360
7	0.110	2830
8	0.093	2380
10	0.078	2000
20	0.033	840

About January 20, 1938, a pre-packed liner was used in the Wilmington field consisting of 6⅝-in. perforated casing inside 8⅝-in. perforated casing with 3/16-in. gravel filling the space between the casings. The pre-packed perforated liner was 240 ft. long and was cemented through perforations above the perforated interval. The liner was quite successful and the well produced through it until October, 1941, when the well was redrilled and deepened.

During the last of October, 1938, a pre-packed liner about 110 ft. long with a 7¼-in. O.D., 7-mesh, 15-gauge iron wire screen was placed in an edge well in the Torrance field. The liner consisted of 5¾-in. casing and 6-7 gravel was used. When the well was placed on the pump, the fluid pumped-off and the well was soon abandoned. It is not known whether the well would have been capable of production with any other type of liner, but it was the general opinion that the formations were completely drained in that area.

The next place where square mesh wire was used in connection with pre-packing was in the Wilmington field. On January 31, 1939, 977 ft. of 5¾-in. casing was landed and included 448 ft. of pre-packed perforated liner opposite three intervals in the productive zone. It was cemented through perforations about 700 ft. below the top of the liner to cover the major part of a 375-ft. blank section. The retaining sheath consisted of 7½-in. O. D., 7-mesh, 15-gauge wire screen and the liner was packed with 8-10 gravel.

On February 7, 1939, before the results obtained with the liner previously mentioned were known, a second operator placed a liner 1002 ft. long in his well. This liner consisted of 769 ft. of 6⅝-in. casing on top with intervals of conventional perforations and 233 ft. of 5½-in. screen type pre-packed liner on bottom. The retaining sheath was 7¼-in. O. D. and 8-10 gravel was used. The liner was cemented through perforations above the pre-packed perforations.

The latter two pre-packed liners gave exceedingly good results and more and more operators adopted the use of screen sheath pre-packed liners.

The next development in pre-packed perforated liners was the use of punch-

Fig. 3. Some of the cuttings removed from a hole by washing and abrading operations when using wall-cleaning guides. Below the rule are samples of dried mud cake

perforated steel plate for the retaining sheath at the Rincon field, Ventura County, California, on August 8, 1939. This plate is thin, inexpensive to manufacture, and has the maximum portion of its area given to openings. Other minor adaptations have been added in the use of retaining sheaths in pre-packed liners, but the iron wire screen and the iron punched plate have been most widely used (See Fig. 1).

It must be called to the reader's attention that the retaining sheaths are incidental to the pre-packed liner. Their purpose is to hold the gravel in position on the outside of the liner and no material strength is required beyond that need. The percentage of surface given to openings does not differ greatly whether wire screen or plate is used. Either will give good results.

Size of Gravel

From the foregoing description of the first pre-packed perforated liners it is obvious that there was no standardization of retaining sheaths or the size of gravel. Considerable study was made regarding the size of gravel to be used and some of the studies indicated that a very fine gravel should be employed in order to keep the sand from running into the hole. As a result there was a time when 8-10 gravel was used to a large extent to prevent sand from entering the well. It soon became noticeable that maximum production was not being obtained from these wells. In later wells the size of the gravel was gradually increased until ¼-in. gravel was used in a sheath ¾ in. thick. The size of gravel has since been reduced in most cases to a maximum of 3/16 in., and the 3/16-in. gravel is now becoming standard for packs with a sheath approximately ½ to ⅝ in. thick.

With the use of the 3/16-in. gravel, a certain amount of fine flour sand can be produced with the oil. One percent sand is not considered dangerous in a new completion. It is quite obvious that, if a small amount of sand is produced, the mud and the filter cake can be more easily removed from the well. The enlarged pore space and the thinnest sheath allows a better opportunity to wash the liner both on original completion and later when there is a tendency for the liner to become clogged.

It has been the practice to select carefully cleaned, well-rounded quartz gravel with the minimum of feldspathic or other material that might deteriorate or wear in contact with fine sand from the well. These gravels are screened for size and are usually designated as staying on one size of screen and passing through the next larger size. Careful attention is given to vibrating the liners while packing in order to pack the gravel into position between the retaining sheath and the liner.

It is also the general practice to weld separating rings to the liner about 8 ft. apart. This prevents settling of gravel for any large part of the liner, centers the pack, and allows shooting for a plug without draining the gravel from the entire length of a joint of the liner before dumping cement.

Lead-seal liner hangers are used to prevent sand from heaving over the top of the liners. The lead-seal hangers are not used if the top of the liner is cemented above the perforated interval.

Throughout the development of the pre-packed liner, several advantages over the conventional pack have been demonstrated, as follows:

(1) Very short and very long liners can be landed in proper position.

(2) The pre-packed liner is adaptable to multiple-zone production and to the use of combination strings.

(3) The gravel is held in position by a retaining sheath so that all portions of the pack are of uniform thickness.

(4) The cost of underreaming in stages and subsequent water loss are diminished.

(5) Bottom water can be more easily plugged-off due to the fact that well shooting is practicable and that the casing is nearer the size of the underreamed hole.

There have been two principal objections raised against the pre-packed liner:

(1) That the retaining sheath acts as an outer casing and that a casing inside of a casing tends to seal-off and prevent the maximum amount of oil from entering the well.

(2) That lignitic materials and waxes will be left in the gravel and gradually seal-off the oil.

It is the writer's opinion that these objections were justified, but the first objection has been virtually eliminated by the increased size of the gravel. The answer to the second objection is that, if the sand were consolidated or if the sand itself contained sufficient large grains to bridge naturally on the perforations, the same effect would be produced and that is not considered a hazard.

Cleaning Pre-Packed Liners

During the early use of pre-pack liners, little attention was given to washing the liners because high rock pressure assisted in the removal of the mud from behind the liners and within the gravel itself. As the oil was heavy,

An advertisement published in The Oil and Gas Journal, 1934

AMERICAN Roller Bearings were selected by rig equipment manufacturers 20 years ago as the No. 1 choice for gruelling, heavy-duty, drilling service. A first choice then, AMERICANS still continue to lead all others in manufacturers' acceptance for Crown Blocks, Draw works, Swivels, Rotary Tables, Pumping units and similar applications. Their leadership is founded upon outstanding performance. Their performance results from specialized design, flawless materials and precision manufacturing. When you "hang the load" on AMERICANS you can expect trouble-free operation. Consult our engineers on any roller bearing problem.

AMERICAN ROLLER BEARING CO.
PITTSBURGH, PENNSYLVANIA
Pacific Coast Office: 1718 S. Flower St.,
Los Angeles, Calif.

AMERICAN *HEAVY DUTY ROLLER BEARINGS*

there was no particular damage done by using water to wash the gravel in the sheath of the pre-pack liners. It early became the practice to use a regular washing tool or to use the swab rubbers opposing each other on home-made equipment and approximately 2 ft. apart on the bottom of the tubing or drill pipe. The tubing or drill pipe was moved until the entire length of perforated interval was thoroughly washed. There were times when the production indicated that the use of the opposing swab rubbers and the water for washing was still not giving best results. The use of lime-treated mud and of acid to react upon the lime-treated mud after the pre-pack liners were placed in the hole was tried without satisfactory results. This was probably due to the fact that optimum conditions were not attained when using the acid.

In the meantime, well-cleaning guides or "scratchers" (see Fig. 2) had been used in connection with removing the filter cake from wells while cementing water strings and in connection with the removal of filter cake from the space behind conventionally perforated liners. For a considerable time it was thought that the abrasive action in connection with washing the pre-packed liners was practicable and desirable. The deterrent was the lead-seal hanger, which allowed insufficient space for circulation and cuttings between it and the water string. After a time a trial method of using the wall-cleaning guides was devised. A string of 338 ft. of 5¾-in. casing, including 320 ft. of 7¼-in. O. D. pre-packed perforated casing, was run to bottom on 4½-in. O. D. drill pipe. A left-hand loose-fitting adapter with centering guides was used at the top of the liner. A tail piece below the adapter to the bottom of the liner consisted of 2½-in. tubing with a series of swab cups facing downward and kept the fluid movement on the outside of the casing. Two rubbers faced each other at the bottom of the tubing with circulation holes between. While circulating water and moving the liner to pass "scratchers", it was noted that thick slabs of mudfilter cake, chunks of shale, and finally oil sand were removed from the hole (see Figs. 3 and 4). It was quite obvious that the abrasive action of the scratchers had removed a large amount of material that could not otherwise have been removed from the well. After the movement of the liner and previous to pulling, the drill pipe was released, allowing the liner to rest on the bottom of the hole. The gravel itself was then washed by raising the drill pipe and tail piece and circulating between the lower two swab cups. After completely washing the liner, the drill pipe and tail piece were removed from the well and the drill pipe was rerun with a special lead-seal hanger. This hanger was of the J-tool type with a left-hand thread on bottom. The left-hand thread was screwed into the adapter and then backed-up sufficiently to set the slips. After standing during the round-trip time of about four hours, the entire 338 ft. of liner was picked-up off bottom and hung on the lead-seal hanger. The well was completed for a larger production than the nearby wells and has continued to be outstanding, although the pressure on the zone has been depleted. It was noted that very little, if any, water was lost to the formation.

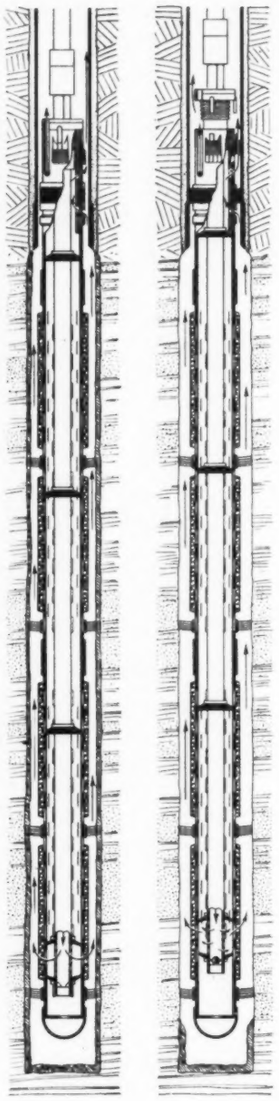


Fig. 4. This assembly has been effective in cleaning behind pre-packed liners. To the left the formation is being abraded. To the right the well is being washed

The next step in the use of abrasive action with circulation of water for the removal of mud and filter cake was a new type of lead-seal hanger. Two manufacturers have developed hangers that would allow the following procedure:

(1) Circulate out the filter cake and cuttings by bypassing the lead seal. This was done by the use of ports in the hanger.

(2) Allow the liner to be hung without closing the ports but at the same time set the seal.

(3) Allow movement of the drill pipe and tail piece until the liner was thoroughly washed.

(4) Close the ports in a simple manner and thereby finally close the space between the liner and the water string.

At the time of writing, wall-cleaning guides in connection with pre-packed liners have been used in 98 wells in the California oil fields, 96 of which were in the Wilmington field. To the writer's knowledge, water has been the circulating fluid for washing in each case except where the hole was drilled with oil, but there seems to be no reason why oil could not be used if the operator preferred.

Not all the mud is removed from the well with the present methods, as was shown by the fact that very little water is lost to the formation after the filter cake is removed. Further work will probably be done in this direction and it is probable that an acid or a deflocculating agent may be spotted back of the liner as a final operation before closing the ports of the hanger.

There are no records of liners becoming frozen off bottom because of the removal of the filter cake. In fact, the opposite is generally the case and the liners are picked up more freely after washing. Operators space their well-cleaning guides 20 to 30 ft. apart as a rule and then move the liner that distance to pass "scratchers".

In the past it has been necessary to use opposing swab rubbers and a washing tool for wells in which a part of the liner was cemented-off or in which a combination string was used. Some of the operators are so confident of the advantages of the abrasive action in use with washing liners that considerable effort is being made to devise means of washing and "scratching" wells under these increasingly difficult conditions. If a method is in sufficient demand, the oil operator or engineer will devise the means and the prediction can be made that this is a step to be expected in the near future.

—— ☆ ☆ ☆ ——

Selective Cementing★

—AND THAT "LAST 10,000 PLANES"

TO fuel that "last ten thousand planes" may be up to the wells being drilled today. Safeguard production by *selecting cement to fit the job.* On these jobs, 'Incor' and 'Starcor' were logical choices:

'INCOR' SELECTED: Big Lake Field . . . 2825′ of 10¾″ casing in 13⅞″ hole . . . temperature moderate. 2000 sacks 'Incor', average slurry weight 15½ lbs. per gal., to cement surface string. Well projected as 8600′ test; whipping of drill-stem in making nearly 6000′ of hole under the string meant heavy strain on pipe . . . Dense-high strength 'Incor' job helped. One of thousands of successful 'Incor' jobs during past 15 years.

'STARCOR' SELECTED: Jefferson Field . . . retainer squeeze, 6100 ft., 196° F.; 20 sacks 'Starcor', slurry weight 16.4 lbs. per gal., pumped into formation, max. pressure 3800 lbs. Well had been making 210 bbl. fluid, only 10 bbl. oil. After squeeze, well made 252 bbl. oil on ¼″ choke, with 0.3% water.

Use 'Incor'* in moderate-depth wells . . . Dense-high strength 'Incor' permits earlier drill-out, wells on production quicker. Use 'Starcor'* for deep holes and high temperatures . . . 'Texcor'† for extra cementing safety in deepest, hottest holes. Select cement to fit the job . . . choose from four Lone Star cements.

*Reg. U. S. Pat. Off. †Trade Mark

SYMBOL OF QUALITY — EVER SINCE 1900

★ SELECT CEMENT TO FIT THE JOB

'TEXCOR' for deepest wells. Extra slow setting, longer and easier pumpability at highest temperatures . . . higher strengths.

'STARCOR' for deep wells. Slow setting; pumps easily at high temperatures. 6 years' successful performance in deep, hot holes.

'INCOR' for wells of moderate depth. Earlier drill out, wells on production quicker. 15 years' outstanding performance.

LONE STAR for all around use, above ground and elsewhere. Portland Cement of outstanding quality ever since 1900.

LONE STAR CEMENT CORPORATION

DALLAS — 'Starcor' . . . 'Incor' . . . Reg. U. S. Pat. Off. — HOUSTON

Rotary Pressure-Drilling Practice

PETROLEUM ENGINEER Exclusive Feature

☆ **Control of circulation pressure on bottom of hole regulates tendency of well to flow**

by E. V. Foran

E. V. Foran is now a Major in the 331st Battalion Engineers, on leave of absence from the engineering firm of Foran, Boatright and Dixon, Houston, Texas, of which he is senior partner. This article was prepared for *The Petroleum Engineer* just before he entered military service.

MODERN rotary pressure-drilling methods as observed in exploratory operations of today are derived from a past experience of nearly 20 years. The first attempt to perform well drilling of this character was made in California in 1924 and was applied to the completion of high-temperature live-steam wells. The conditions imposed upon the drillers were severe. The success of this venture made it evident that pressure drilling might be applied to certain oil-field drilling practices in which the physical hazards were comparable, at least with respect to the high-pressures encountered in the progressively deeper exploratory work throughout the country. Among the more notable of the early successes of pressure-drilling operations were those carried out in Kettleman Hills about 1930. At this time the reconditioning of the Milham Exploration Company's No. 1 well in the Kettleman Hills field required that the tubing string, which was in bad condition, be pulled and replaced without killing the well. The operations as conducted on this well were performed while the well was flowing under a back-pressure at the surface of from 1000 to 1200 lb. per sq. in.

Objectives

The primary object of pressure drilling is to control the circulating pressure on the bottom of the hole for the purpose of either suppressing or increasing the tendency of the well to flow. The control of such operations may often extend through a range sufficient to cope effectively with a potential high-pressure blowout or to "drill-in alive" when making a completion in a producing horizon of subnormal pressure. It is apparent that to attain such objectives, equipment other than that conventionally used in rotary drilling will be required. A method of application suitable to local conditions must also be applied in conjunction with the particular drilling equipment used. Pressure drilling is not limited to depth, the records revealing that it has been carried out under prevailing conditions at depths from 3,000 to 12,000 ft.

Equipment

Pressure-drilling operations as conducted at the present time may use rotary tables of the hydraulic or conventional type, with the hydraulic table having the advantage that it may readily perform all the operations common to the conventional type and in addition may function with its inherent advantage of a hydraulic table. Pressure-drilling equipment requires a set of snubbers for the purpose of running-in or pulling-out the tubing or drill pipe under prevailing high back pressures at the surface. These snubbers may be operated hydraulically or off the drum, depending upon the choice of the operator. The hydraulic-type snubbers are operated independently of the drawworks or drum and offer certain advantages. The drill pipe used in these operations is generally of the external flush-joint type although an external thin streamlined upset joint may serve equally well. In addition to the equipment named, there may be used as necessary accessories, back-pressure float valves in the drill pipe, a stop-cock type of valve near the head of the kelly, and mud chokes or valves for control of back pressure on the return circulating mud or other drilling fluid at the surface. The casinghead should be equipped with an automatic pressure-tight drilling head.

Methods

The choice of drilling methods will depend somewhat upon the conditions to be expected in the various formations penetrated by the bit. While drilling ahead and approaching high-pressure horizons, it may often become necessary to suppress the activity of a well after penetrating the high-pressure gas zone. This requisite is attained by regulating the effective weight of the mud by applying additional back pressure on the circulating returns at the surface. Although application of back pressure in this manner does not change the density of the mud, it does instantly change the effective pressure of the mud on the bottom of the hole. In operations of this character, sudden and rapid changes in the effective bottom-hole circulating pressures may be increased by 1000 lb. per sq. in. or more. On the other hand, if the drill is approaching a productive horizon of sub-normal pressure, it may be desirable to decrease the bottom-hole pressure and promote the entry of the oil and gas into the well bore. This situation will require that the operator reduce the normal circulating pressure at the bottom of the hole to the extent that the pressure existing within the horizon being penetrated may equal or exceed that of the circulating pressure on bottom. Under this condition, the well would have a tendency to flow while drilling-in unless otherwise suppressed. When it is desirable to allow the well to flow while being drilled-in, it is essential that either clean water or oil be used as the circulating fluid. The use of mud under such conditions would result in the emulsion of the products at the surface, which could not be treated for disposition. Experience in the use of clear water or crude oils as drilling fluids indicates that these fluids are permissible in well-consolidated formations such as limestones and hard or well-cemented sandstones.

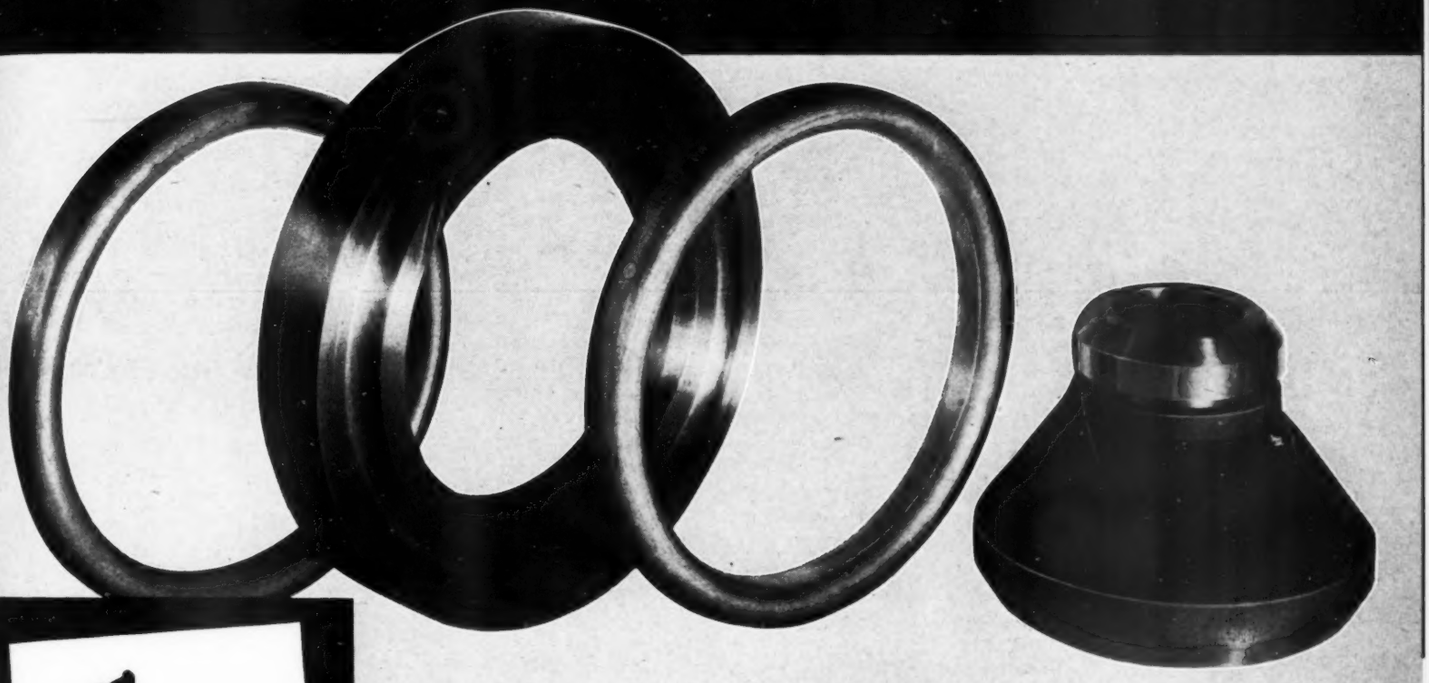
Present-Day Application

In reviewing the progress of rotary pressure-drilling methods to the present time, it would appear that rather limited progress has been made. This is due in part to the difficulty of reducing such practice to a routine basis as well as to the fact that alternatives have been developed that may be substituted with an acceptable loss of advantage to the operators. During the last 10 years there have been developed, for example, various methods for detecting to a qualitative degree the character, extent, and position of the various producing zones penetrated by the bit. These detectors may take the form of electrical surveys in which the productive data sought are qualitative and indicative. The fluoroscope has been widely used in recent years, especially in wildcat wells, to detect the presence of gas and oil by the ex-

This Reversible Disc is the Secret to

DOUBLE LIFE

in Hunt All-Steel Line Valves



STANDARD

HEAVY-DUTY

HUNT *All-Steel Line Valves* feature a reversible disc and seat of stainless steel, which gives double the life of ordinary valves. The seat, or ring, is of a lower Brinell Hardness than the disc, assuring positive seal as the disc and seat wear. The same disc and seat will fit any of the various valves of the same size, whether screwed or flanged.

The construction of Hunt All-Steel Valves is such that it is unnecessary to remove the valve from the line to reverse or renew the seat or valve. Simply remove the flange bolts, and raise the bonnet sufficiently to clear the seat. Valves can be repacked under pressure, as bonnet top has a machined recess which seals the valve around the stem when it is in full open position.

Hunt All-Steel Valves are space savers, too. Unnecessary connections are eliminated, and the compact design reduces space requirements to a minimum.

HUNT TOOL COMPANY

FIELD SHOPS:
Houston, Bay City, Corpus Christi, Jennings, Shreveport, Harvey

EXPORT SALES:
W-K-M Company, Inc.
74 Trinity Place, New York City

HUNT TOOL COMPANY
HOUSTON, TEXAS, U. S. A.

amination of the returned cuttings in the circulating stream. This determination likewise is qualitative but quite positive. The recoverable cores as received from the core barrel also disclose the character of the productive formations with a nearer approach to the quantitative than either of the above two methods. If the occasion arises in which it becomes desirable or necessary to determine, in a quantitative sense, the productive character of the formation foot-by-foot it appears that a "live well" completion is the only course open to the operator.

Although the "live well" completion is one of the outstanding advantages to be gained by the use of adequate pressure equipment, there are others of equal importance. Among the other advantages is the ability of the driller or operator to change the effective pressure at the bottom of the hole rapidly, irrespective of the density of the circulating mud. No other method devised to date enables the operator to meet so quickly the unforeseen requirements of increased pressure on bottom when blowouts are threatened. This applies to shallow or deep well drilling and in wildcat or familiar territory. With a properly equipped pressure-drilling layout, whether on a wildcat well or not, nothing but gross negligence would result in a well getting out of control. In most cases of record in which damaging blowouts have occurred, it would have been within routine practice, when pressure equipped, quickly to have applied, for example, 500, 1000, or 1500 lb. additional pressure on the bottom of the circulating column to suppress totally and bring within control a blowout in its incipient stage. This inherent advantage available only in pressure-drilling equipment has no alternative or parallel in other drilling methods in use to date. It is not necessary to discontinue either circulation or drilling ahead while applying this emergency measure.

In some cases, high-pressure porous zones may be filled entirely with salt water whose encroachment into the hole during drilling will result in dilution of the mud and so reduce its density and alter its physical character. While drilling with conventional equipment the presence of thick super-pressured salt water sands may bring about abandonment of the effort to drill the well deeper unless special treatment involving considerable expense is administered. These conditions have frequently been encountered both in California and the Gulf Coast. An example of pressure drilling involving a problem of this character has been presented by Cashion.[1]

[1]"High-Pressure Salt-Water Flow Need No Longer Spell Defeat in Drilling Operations," by M. L. Cashion, Assistant Superintendent of Production, Houston Production District, Gulf Oil Corporation, *The Petroleum Engineer*, August, 1940.

Limitations of Practice

Certain applications to which pressure-drilling equipment is most favorable are limited to consolidated formations. "Live well" completions must be restricted to formations of the consolidated character due to the fact that at times the pressure maintained on the bottom of the hole is less than the prevailing pressure within the productive formation. Any attempt to drill-in with a bottom-hole circulating pressure less than that existing in the formation in the case of an unconsolidated sand is certain to end in failure and difficulties whose risks do not justify the attempt. In consolidated formation, there should be no difficulty encountered in drilling ahead "alive" after the casing has been set and cemented. Any effort to drill-in "alive" before setting the casing would, of course, be extremely hazardous and most likely would result in failure. While drilling "alive" through high-pressure formations, the amount of circulating water may be greatly reduced, probably in the amount of 75 bbl. an hour, in which case any section of the producing zone having good permeability will produce freely and may require some back-pressure restriction at the surface. The water and oil or water and gas-condensate may be readily separated on the surface through a high-pressure separator with a minimum of cut oil resulting.

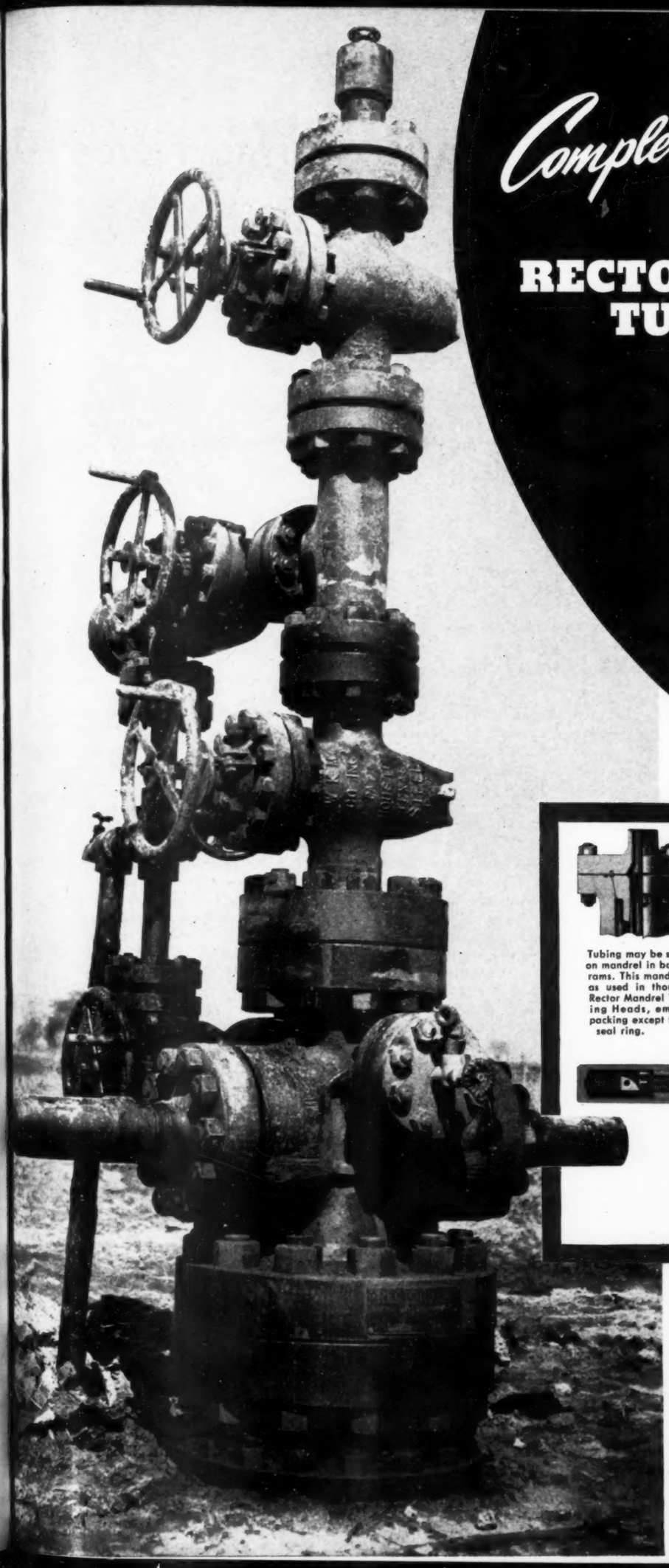
In dealing with unconsolidated formations, the use of pressure-drilling equipment will serve only as an additional factor of safety. These formations will not permit the "drilling-in alive" due to their tendency to creep or heave under subnormal circulating bottom-hole pressures. In those cases in which wells below 10,000 ft., for example, encounter super-pressured sands of great thickness, it may be necessary to maintain a very high density mud while drilling through it in order that operations may be carried on without encountering too high back pressures on the circulating returns at the surface. Even if the formations are consolidated and permit the use of balanced or sub-normal circulating pressures on bottom permitting drilling-in "alive," the back pressures on the surface while pulling out the drill pipe may approach shut-in pressure at the wellhead, a condition probably too severe to warrant "live well" drilling in this case. When sands of great thickness such as these are super-pressured, there would naturally be little requirement for a "live" well completion.

The Wildcat Well

Pressure-drilling equipment may be expected to serve its best purpose when properly equipped on wildcat or deeper exploratory wells. In undertaking a wildcat project, the operator is confronted with the problem of observing very closely the shows of oil or gas throughout any section that the bit penetrates. It is customary with conventional equipment to use a mud of such weight or density that it may be perfectly safe in penetrating unexpectedly high-pressure zones in wildcat territory that may have permeabilities sufficient to allow blowouts to develop. Examination of the samples from these circulating returns while drilling is the only means of determining the presence of such shows of production and the evidence of productivity must be dependent more or less upon limited observations. On the other hand, when the wildcat well is properly equipped for pressure drilling the effective weight of the mud may be controlled by application of back pressure on the circulating returns and a minimum of pressure may be maintained on the bottom of the hole in order that reactions when penetrating potentially productive zones will be more sharp and impressive than when suppressed by the weight of high-density mud. The danger of blowout under these conditions is negligible, as high back pressures may be almost instantly applied at the surface if safety calls for such measures. After casing is set in a wildcat well, the well may be completed with safety while the well is flowing. If the wildcat zone penetrated has sub-normal pressure there is little that can be done to drill a well in "alive" unless an extraneous source of high-pressure gas is available at the well, in which case the gas may be introduced into the drill pipe simultaneously with clear water in such proportions that the circulating pressure on bottom is at all times less than that existing in the formation. This procedure, of course, is dependent upon formations being of a consolidated character. By a consolidated character in this instance is meant one that will not cave or heave while the well is flowing in a normal manner.

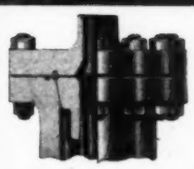
In performing pressure-drilling operations in either wildcat or familiar territory, operators may sometimes take the position that substitute equipment of second grade may be sufficient to accomplish the objectives sought. A decision to undertake work of this character with that objective in mind adds to the venture a speculative element that has no place in such operations. The equipment available in pressure-drilling operations today is sufficient to attain economically and practically any objectives sought within the scope of these operations.

☆☆☆

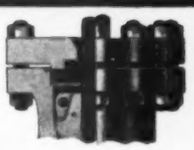


Complete Wells Safely

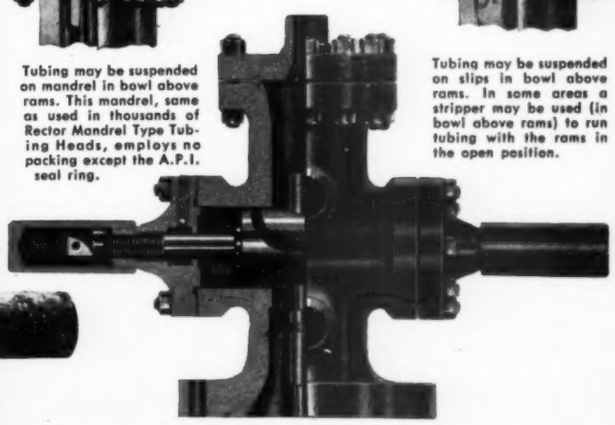
RECTOR ROUND RAM TUBING HEAD



Rector Round Ram Tubing Head showing tubing suspended on rams.



Tubing may be suspended on mandrel in bowl above rams. This mandrel, same as used in thousands of Rector Mandrel Type Tubing Heads, employs no packing except the A.P.I. seal ring.



Tubing may be suspended on slips in bowl above rams. In some areas a stripper may be used (in bowl above rams) to run tubing with the rams in the open position.

RECTOR WELL EQUIPMENT CO. INC.
"MAKING THE OIL INDUSTRY SAFER"

RECTOR WELL EQUIPMENT CO., INC.
FORT WORTH, TEXAS, U. S. A.

Representatives in All Active Drilling Areas
Export Agent: LUCEY EXPORT CORPORATION
Woolworth Building, N. Y. C.
Sold by Leading Supply Companies

Mud Analysis Logging in California Fields

PETROLEUM ENGINEER Exclusive Feature

☆ **Portable equipment complements electrical logging and testing operations—proves useful in coring control**

by Wallace A. Sawdon
Pacific Coast and Foreign Editor

THE logging of oil and gas bearing strata in California by means of mud analysis has been confined principally to wildcat or exploratory operations. The results obtained, however, have indicated prospects for use in proved areas, particularly for completions in horizons where gas in the upper part of the producing zone is to be cased-off at a point that will give a desired gas-oil ratio. The method also supplies valuable data in proved fields where considerable faulting is encountered and to supplement coring when core recoveries are questionable. Mud analysis logging is performed during the actual drilling of a well and is a complement to electrical logging and testing operations, but in addition it has been found useful in many phases of the drilling program and has been especially valuable as a control to coring when physical cores are to be taken.

Equipment Portable

The equipment employed in mud analysis logging is housed in a trailer that is transported to the well as described in a previous article.[1] Briefly it consists of a depth meter that indicates the total depth of the hole and the location of the bit in relation to bottom; a pump cycle counter and meter showing the rate at which the pump is operating in cycles per min.; a gas detector, and an ultra-violet light apparatus for oil detection. A sclerograph, operating in connection with the depth meter, records the drilling rate, instrumental gas readings, pump cycle counter readings, and power applied to the rotary table. Also included in the trailer is complete core analysis equipment for determination of permeability, porosity, and residual fluids of any cores that may be taken. Electrical equipment employed is operated by 110-volt, 60-cycle alternating current and when direct current is being used on the rig it is converted to alternating current by a motor-generator set mounted in the trailer.

[1] "Mud Analysis Used to Log Wells While Drilling," by Wallace A. Sawdon, *The Petroleum Engineer*, August, 1939.

During drilling the bit drills-up and disintegrates a circular core of the formation and the gas, oil, or salt water contained in the pore spaces of this core are picked-up by the drilling fluid. By analyzing continuously the fluid upon its return to the surface and correlating for depth, the gas, oil or salt content of the formation at the point drilled can be determined. Due to the salinity of the mud fluid generally used in California accurate determinations of salt-water content of the formation are difficult to make and it has been the practice in California to confine the logging to gas and oil determinations.

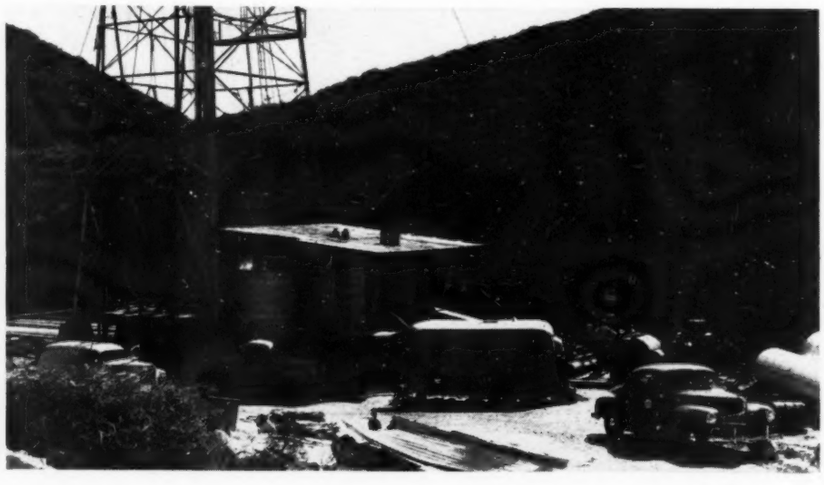
Continuous Record Provided

The continuous records of the drilling rate and fluid content of the formation as supplied by the mud analysis log are shown in Fig. 1, together with electrical log curves taken in the same well after it was drilled but before casing was run. The dotted record of the fluid log indicates gas and the solid line oil.

The logs comprising Fig. 1 were taken in a proved field and indicate how the mud analysis fluid log assists in interpreting the electrical log. The entire distance logged shows stratified saturation, but the fluid log identifies that above 7950 ft. as being almost entirely gas. To keep down the gas-oil ratio it was necessary to case-off the upper portion of the producing zone so the casing was cemented at a break just below the top of the highest predominant oil indication. The liner run to bottom was perforated below the cementing point to 8250 ft. The gas-oil ratio when the well was put on production was 1680 cu. ft. per bbl.

The general practice followed in California, when mud analysis logging equipment is used during the drilling of a wildcat well, is to take cores of all gas- and oil-bearing formations indicated by the logging equipment. The drilling rate curve is first utilized in this procedure, as a significant increase in the rate indicates a change to a softer, more rapidly drilled formation, usually sand. After penetrating from 3 to 5 ft. into this softer formation, drilling is suspended but circulation continued until the mud at the bit reaches the surface when it can be analyzed for oil or gas content. If the mud shows oil or gas, cores are taken; if not, drilling is resumed until another break is indicated and the procedure repeated. This eliminates the necessity for coring shale or other non-productive formations.

The coincidence of increase in drilling rate with findings of gas or oil in the formations more rapidly drilled is indicated by the drilling rate and fluid log curves in Fig. 1. This log was taken through a producing zone in a field where gas and oil were known to be present. It is of particular interest because it shows concisely the performance of the equipment in a stratified producing zone and determines the rel-



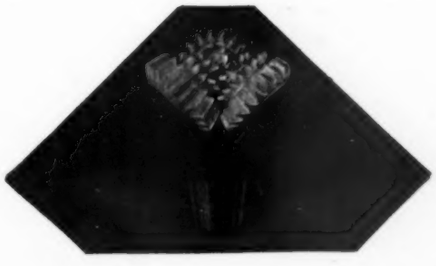
At a wildcat well in California. The trailer is hauled to the well and left there for logging operations

105-mm. HOWITZER — Photo by U. S. Army Signal Corps.

Anticipating the need...

THE EMPHASIS on fire-power in modern war pointed to the need for heavier "light" artillery—result was the development of the 105-mm. piece, which fires in either a flat or arched trajectory and is in effect a combination gun-howitzer.

The emphasis on speed in drilling led to Hughes Tool Company's development of "Tailor-Made" Rock Bits—and today Hughes Bits are being used from "grass roots to casing seat" to speed the drilling for oil needed to "keep 'em firing."



Hughes Tool Co., Houston, Texas

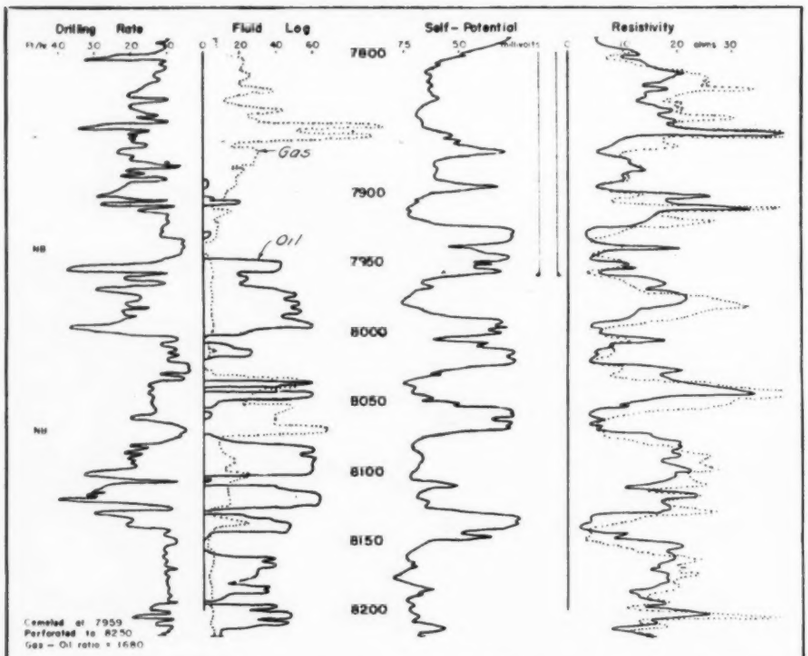


Fig. 1. A sample of the continuous record of drilling rate and fluid content of the formation as supplied by the mud analysis log

ative depths of the gas and oil strata.

The drilling rate and fluid curves of a wildcat well are shown in Fig. 2. In this well rotation was discontinued but circulation continued at 6355 ft., where the drilling rate showed considerable increase. No appreciable showings of oil and gas were indicated, however, so drilling was resumed. The hole was circulated again at 6500 ft. and, as there were showings of oil and gas, coring was begun and continued to 6605 ft. The cores were analyzed but indicated probable salt water.

There was another break at 6615 ft., but this was not cored, as there was not enough section. Drilling was carried to a depth of 7000 ft. where, after circulating, a slight showing of oil was indicated. The hole was cored from there to 7037 ft. No showings were picked-up by circulating at 7160 ft. so the well was drilled to bottom.

The section from 6490 ft. to 6630 ft. was drill-stem tested and showed considerable gas, some oil, and a lot of salt water. This result had been predicted from the mud analysis log and core analysis data.

Although side-wall sampling is not being done to any great extent in California it would seem that the use of wall samplers might be applied to advantage in connection with mud analysis logging. In other areas of the United States exploratory wells are sometimes drilled without conventional coring by taking wall samples of prospective formations indicated by the mud analysis log. The wall samples check the lithology of the formations and the mud analysis log prevents passing-up of possible commercial production that might otherwise be missed. This procedure has been found advantageous when high formation pressures were encountered or when sloughing shale made coring difficult or impossible.

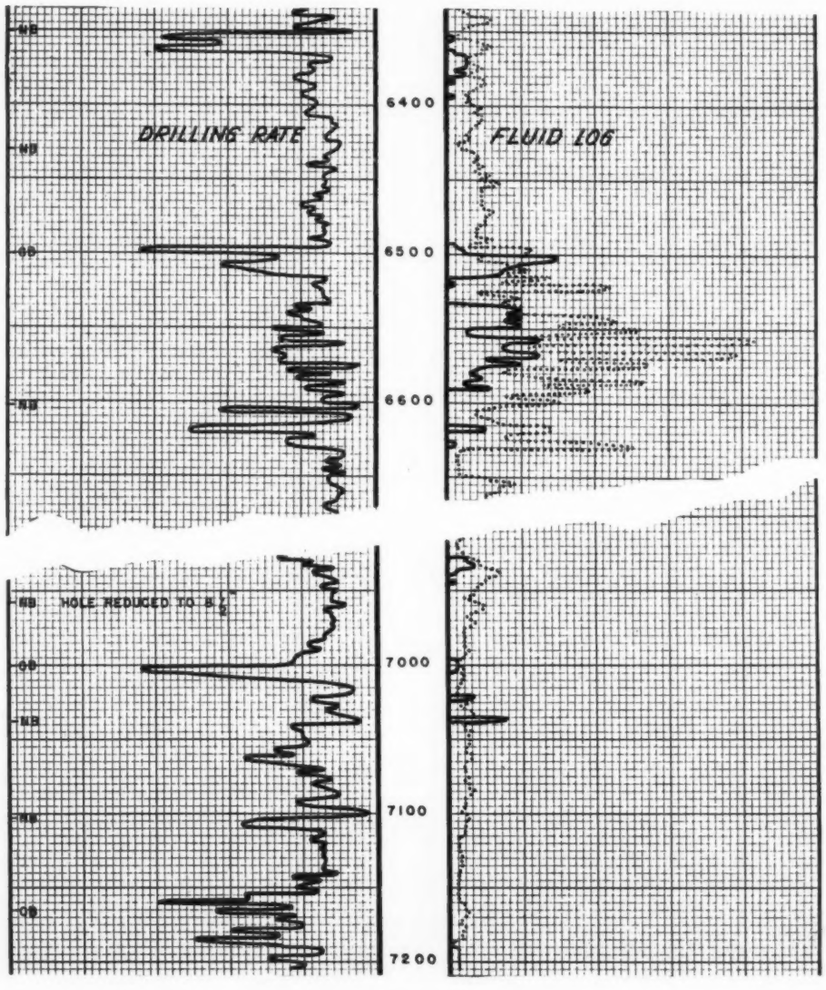


Fig. 2. Drilling rate and fluid curves taken on a wildcat well

Indicates Fluid Content

In addition to determining the oil-gas contact in producing zones the mud analysis log will complement the electric log by indicating the fluid content of a possible formation indicated by both. In a certain gas area of California a sand was picked-up by increased drilling rate. No gas, however, was indicated by the mud analysis. The electric log showed the same sand and the resistivity curve had a good kick that correlated with a producing well in that area. On making a test the sand was found to carry fresh water.

During the taking of mud analysis logs the operator has before him instruments showing certain perform-

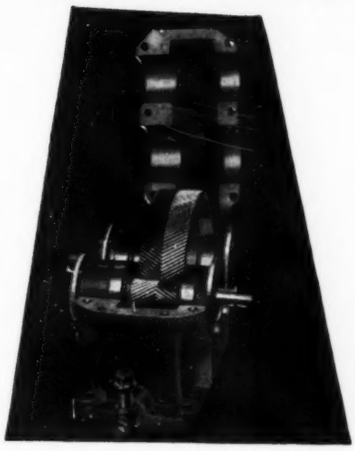
Correct SPEED *to keep 'em pumping* AT FULL EFFICIENCY

Link-Belt enclosed herringbone gear unit equipped with 75 H.P. motor, in refinery, operating a Kinney topping-off pump, handling 500 G.P.M. of fuel oil at a pumping speed of 268 R.P.M. against a discharge head of 378-ft. Another pump, equipped with a similar Link-Belt speed reducer and 300 H.P. motor, handles 3000 G.P.M. of fuel oil at pumping speed of 175 R.P.M. against a discharge of 378-ft.

● Link-Belt enclosed herringbone gear speed increasing and reduction units are outstanding in the field. Here are just a few of their many features:

Gears—continuous herringbone type—Sykes tooth form, using 20 degree pressure angle, 30 degree helical angle—involute teeth. Made of heat treated alloy steel forgings or electric alloy steel castings.

Housings—neat, sturdy, oil-tight, dust-proof—cast gray iron—of proper size to dissipate any heat generated within the thermal rating of unit.



Types—made in single, double and triple reductions up to 1000 H.P. Ratios 10:1 to 318:1.

Units are anti-friction bearing equipped throughout—with oversize bearings on the output to permit overhung loads. Leak-proof seals on high and low speed shaft projections keep grease in and dirt out. Complete data in 32-page Book No. 1519.

We also make Speed Reducers of the Worm Gear and Motorized Helical Gear types. Send for Catalogs Nos. 1515 and 1524.

LINK-BELT COMPANY

Philadelphia Dallas Houston Los Angeles Kansas City, Mo. New York Toronto Distributors in all fields 8107

This wheel arrangement is set in the mud stream and provides samples for detecting oil

ance features of the drilling rig. On rare occasions when steam pumps are being used a gradual and continuous increase of pump speed as shown by the pump meter will be observed. This will frequently mean an incipient washout. The increase in such a case is so gradual that the driller will not notice it, but when called to his attention he can pull the tools. On one job such an increase of speed was observed and continued to become greater. The driller was informed, but it was not until the next driller came on the job that the full gravity of the condition was realized. He immediately began pulling the drill pipe, but it parted before the tools were out of the hole. The trouble was reported five hours before the string was pulled.

Actions in Hole

In regard to the detection of oil and/or gas by mud analysis it is necessary to consider the action taking place in the hole during drilling. The additions of oil or gas to the mud are from that portion of the formation drilled-up by the bit and not an inflow from strata previously penetrated. It has been found that this inflow from formations above the bit will seldom occur when the static head of the fluid column is greater than the formation pressure. Inflow from permeable formations is further retarded by the filter cake, which forms rapidly when mud of adequate wall-building qualities is used.

The magnitude of the oil and gas showings is influenced to some extent by the actual making of hole. As the bit cuts the formation there will be some water loss from the mud into a permeable stratum and this will tend to flush back into that stratum some of the oil and gas released by disintegration of the core as it is cut by the bit. How much of the total fluid content of the drilled-up core is taken from the circulating fluid depends on several factors, but the flushing action is not sufficient to rob the mud fluid of any great part of the oil and gas content.

The two important factors influencing the flushing effect are rate of drilling and weight of the mud. Fast drilling provides higher readings and the showings are greater when the differential pressure across the face of the sand is low. The porosity and permeability of the sand, viscosity of the oil, gas saturation, and even the character of the mud will all affect the percentage of fluid content deposited in the circulating fluid.

Emulsification of the oil in its passage from the bit to the surface is the only cause of decreased detection after the oil enters the circulating stream. The tendency to emulsify is greater in a mud whose content of solids is high, and is increased by length of travel due to depth. Good mud is therefore desirable although the tendency to emulsify is small in the viscous type of flow through the annulus around the drill pipe.

In the latest design of logging unit the mud is pumped from the well discharge through the portable laboratory where the gas trap and sampling device are. This has been found to facilitate operations and to regulate and standardize the operation of the various elements. The weight on the bit is now accurately recorded and this aids in the interpretation of the drilling rate log. Tests are being made on a drilling rate meter that has an automatic compensation for the weight on the bit in order to make the drilling rate log more nearly proportional to the work done by the bit. This will provide a reliable index to formation hardness.

It appears from results obtained that mud analysis logging provides reliable qualitative data on oil and gas saturation of formations drilled. As with other subsurface information, the results should be evaluated in connection with all other data obtained.

—— ☆ ☆ ☆ ——

The gas trap is here shown mounted with connection to the mud ditch. Gas goes from trap to the testing trailer. In the latest designs the trap and sampler are in the trailer

Arkansas' Oil and Gas Industry Managed on Engineering Basis

Exclusive

☆ State's conservation statute has gained national recognition for wisdom of its provisions—Oil and Gas Commission highly successful as a regulatory body

by Alec M. Crowell

Director-Engineer, Arkansas Oil and Gas Commission

THE State of Arkansas has been seriously in the petroleum and natural gas engineering business for the last four years and with satisfactory results. Reserves of oil and gas have been constantly added; the Ouachita Valley has war industries operating on natural gas; commercial sulphur to compete with the Gulf Coast is a by-product of the gas business; costly secondary recovery methods of production are being avoided; the state has saved its citizens and the industry millions of dollars through a conservation policy designed on an engineering basis, and availability of petroleum coupled with a strategic location is allowing the state to contribute on a major scale to the war effort. Engineering work goes on; there is more drilling development this year than last, all supervised by a state agency at no cost to the general taxpayer.

There is one fundamental difference between a farmer or landowner in the oil counties of Arkansas and in any other part of the oil country of the United States. The Arkansas farmer or landowner, whether or not oil or gas production is on his property, has a working knowledge of oil terminology and production practice. Transferring his knowledge of the oil industry into words might fall short of the glossary of terms relating to oil and gas reservoir behavior, as set up by the American Petroleum Institute's Committee on Production Technology; nevertheless the meaning would be well understood by any petroleum or natural gas engineer.

This particular knowledge of the people of Arkansas, most authorities connected with the petroleum industry agree, is responsible in considerable measure for the fact that the oil and gas pools of Arkansas are among the best managed in the history of the industry. It is being proved from day to day that good management is saving millions of dollars to the people and to the oil industry.

ALEC M. CROWELL

began his engineering career 16 years ago with the Empire Oil and Refining Company of Bartlesville, Oklahoma—After four years, 1926-1930, on that company's properties in New Mexico, Oklahoma, Kansas, and Texas, he accepted a position in California with the Del Rey Oil Company—After two years in California, 1931-1932, he returned to the Mid-Continent with the Shamrock Oil Company of Amarillo, Texas—A year was spent on construction of the Panhandle's largest gasoline plant and then he became affiliated with the Oil and Gas Division of the Texas Railroad Commission—During five years, 1933-1938, as director of field engineering and research, he personally inspected and reported on more than 300 oil or gas fields—Went to Arkansas in March, 1938, to organize and direct the operating personnel of the Arkansas Oil and Gas Commission—Educated as a mechanical engineer at the University of North Carolina and natural gas engineer at the University of Kansas, he has written many articles on conservation, optimum production rate, well-spacing, and related subjects—Is a member of the American Institute of Mining and Metallurgical Engineers, American Society of Military Engineers, and a registered professional engineer in the states of Texas and Arkansas.

Reserves

When the present conservation policy of the State of Arkansas was first adopted early in 1937, the existing reserves of petroleum were estimated to be only 87,000,000 bbl. Between January, 1937, and January of this year, 103,000,000 bbl. of oil were produced and still it is estimated that more than 370,000,000 bbl. remain. More than 386,000,000 bbl. of new oil reserves have been discovered during the first four years of the present conservation plan. The difference in the reserves of January 1, 1937, and the reserves of January 1, 1942, disregarding the production between those dates, gives an increase of 325 percent.

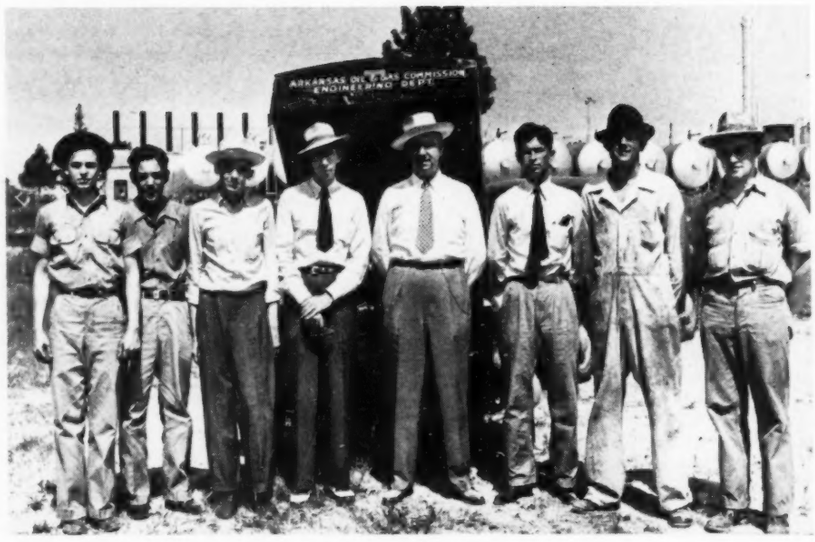
While this substantial reserve of oil for so small an area was being discovered, more than 900,000,000,000 cu. ft. of gas was found. This tremendous supply of gas has been responsible in large measure for the building of some nine war industries in or near the Ouachita Valley of Arkanas. These reserves of oil and gas are being supplemented consistently and the yearly depletion rate of known reserves is now only approximately 7 percent. These reserves are so managed that they are readily available to supply civilian and military needs in this time of war.

Strategically, the oil counties of Arkansas (Columbia, Lafayette, Miller, Nevada, Ouachita, and Union) are so situated as to be of particular value in the movement of petroleum to the eastern seaboard of the United States, where at present a serious shortage exists. With the movement of oil greatly curtailed through the usual shipping channels by diversion of tankers and the submarine hazard, the premature

decline of oil production due to production practice in the states of Illinois and Mississippi, and the natural decline of production in the State of Oklahoma, the availability of sustainable oil production in Arkansas is a worthwhile contribution to the war effort. Although Federal production certifications have declined for some other states and drilling exploration has declined in practically all oil-producing states, Arkansas is supplying practically the same amount of oil per day as it was prior to the entrance of the country into war. There are more wells drilling in the state this year than last. The oil industry of Arkansas is sound and profitable.

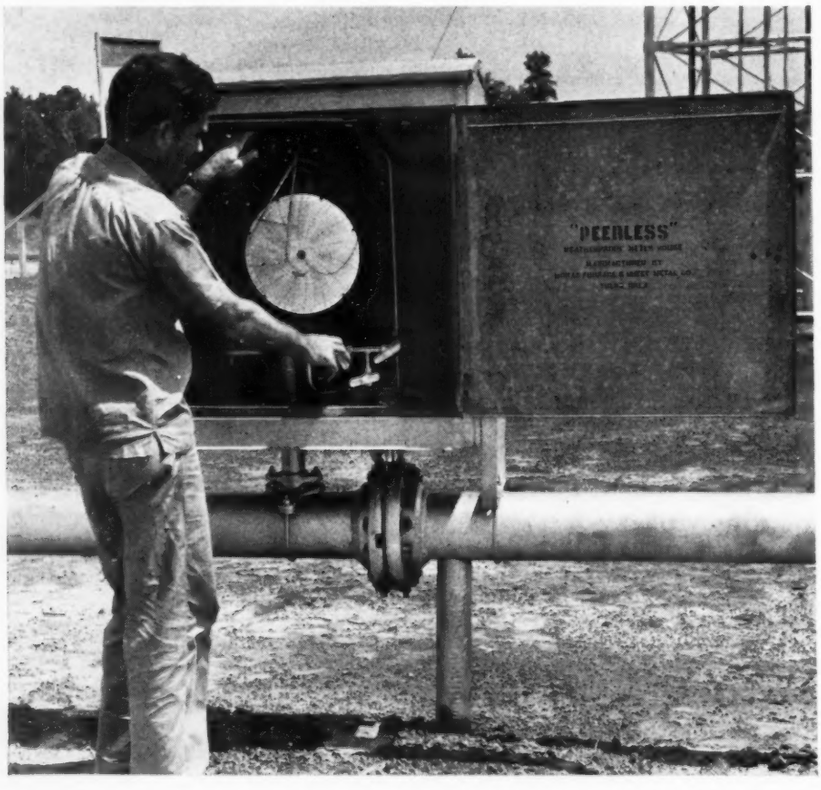
Oil and Gas Commission

Credit for the admirable position of the Arkansas oil industry should go first to the state legislature. Its wisdom in enacting a conservation statute that embraced all the fine points of conservation laws proved throughout the years, together with proved production policies recommended by the modern petroleum engineer, has gained not only national recognition but insured the ultimate benefit to the state from an irreplaceable resource.



Qualification is the basis of employment of the Commission's engineering personnel, as can be noted from the colleges and universities represented by these men: Jack Vestal, University of Oklahoma; L. L. Jordan, Ouachita College; J. B. Webb, University of Mississippi; E. M. Dutton, Texas Christian University; Alec Crowell, Universities of North Carolina and Kansas; C. H. Thigpen, University of Louisiana; C. V. Lisman, University of Arkansas; Arthur G. Burki, University of Pittsburgh. Two engineers not present are J. R. Harrison, Texas College of Arts and Industries, and J. H. Waddle, University of Oklahoma

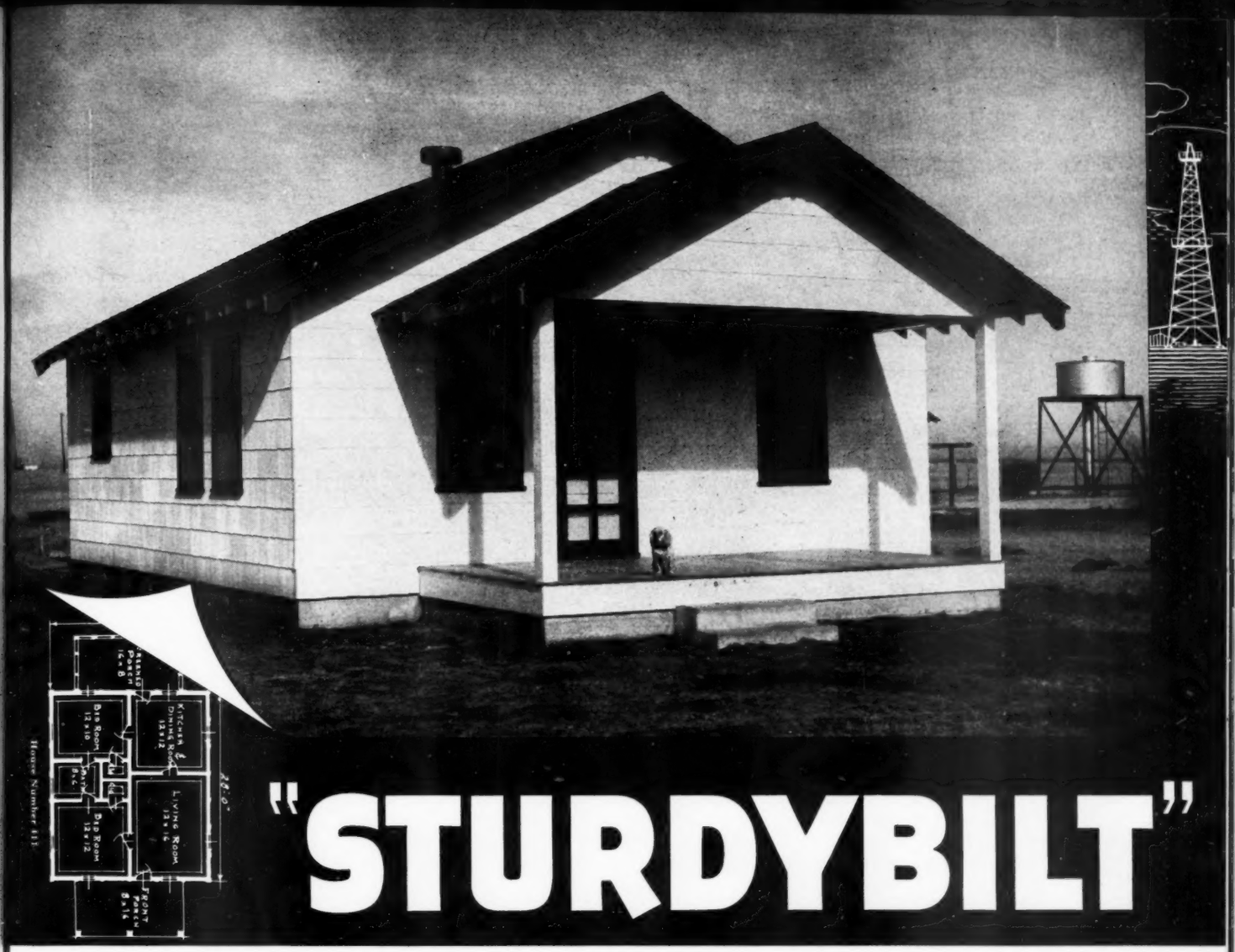
Making a gas-oil ratio test. An engineer of the Commission checks the measurement of gas from a lease. At the end of this meter run, and not shown in the picture, is a portable metal bellows type orifice meter mounted on a movie camera tripod with which the engineer checks the correctness of the company-operated meter. The state forbids the wastage of any gas to the atmosphere from an oil or gas well or the use of this gas in the manufacture of carbon black or for inefficient purposes



The administrative agency, the Oil and Gas Commission, is a little unusual among regulatory bodies, but has been highly successful. The members of the commission are appointed by the governor for staggered six-year terms. They receive no remuneration other than a per diem of $10.00 to cover personal expenses to their one day quarterly meetings. Selected by the seven members of the Oil and Gas Commission is the administrative officer and under his supervision a group of petroleum engineers, natural gas engineers, geologists, statisticians, oil accountants, and others to carry out the rules, regulations, and investigations required by the commission. Qualification has been the only factor in the selection of the employees of the commission.

The petroleum and natural gas engineers of the Oil and Gas Commission are largely responsible for the familiarity of the people of Arkansas with oil and gas terminology. These men, all well qualified, are in constant touch, not only with the producers of oil and gas but with the landowner and royalty owner as well. They are trained to take time off, if necessary, to acquaint any legitimate interrogator with their work and the reason behind their activities.

Two farmers who own land in oil



Sectional Houses
FOR THE OIL INDUSTRY

"STURDYBILT" took the canvas out of oil field camps. They can be speedily and economically erected at temporary or permanent locations. **"STURDYBILT"** houses provide attractive, comfortable and conveniently arranged living quarters.

These factors of value cannot be discounted in setting-up an oil field housing program — **Prefabrication** cuts erection time from days or weeks to only hours — **One Billing** covers all costs — **Standardization** of designs assures better houses at lower costs — **Demountability** provides high salvage, there is very little capital loss if houses have to be moved to a new location.

OIL FIELD TYPES — all practical and each designed to fill a specific housing requirement: Residences, one, two, three, four and five rooms; Boarding and Bunk Houses; Recreation Halls, Warehouses and Field Offices, Garages and small buildings. Floor plans, together with quotations, will be sent promptly upon request.

SOUTHERN MILL & MANUFACTURING CO.

Wichita, Kansas **TULSA, OKLAHOMA** Longview, Texas

fields, one in the Village field of Columbia County and the other in the Buckner field of Lafayette County, met one day. The landowner from Village, in asking his friend, the landowner from Buckner, about bottom-hole pressure, referred to the subsurface or reservoir pressure of the Buckner pool. He was simply answered that the pressure was unchanged and that he expected no change in his royalty payments. Had the answer been that the bottom-hole pressure was dropping, it would have been almost a settled fact his royalty payments would decrease due to the curtailment in production quotas as fixed by the State.

Pressure Maintenance

Pressure maintenance is the keynote of production control in the State of Arkansas. Prevention of the necessity of costly secondary recovery and repressuring operations, except when naturally necesary, is the prime objective. Fortunately, all oil and gas reservoirs brought into production since January, 1937, which marks the date that the state instituted its system of production control, are pools with very effective water drive with the exception of one.

A complete staff of qualified petroleum and natural gas engineers is necessary in the operation of the regulatory system based upon maintenance of reservoir pressure. To fix, as allowables, optimum production rates that will insure maximum percentage of oil recovery to minimum percentage of pressure decline, the physical make-up of the oil and gas reservoirs must be known. Porosity, permeability, rate of water encroachment, original reserves of oil and gas, and other factors must be available.

Maintenance of reservoir pressure results in the conservation of energy and prolongation of the flowing and producing life of any oil and gas field. Physical changes in the oil, brought about by excessive pressure decline, are usually detrimental to the efficient and ultimate recovery of oil from any pool. For instance, continued decline in reservoir pressure releases more and more gas from solution with the oil and thus increases the operating gas-oil ratio for any pool. The inherent energy of this added gas production could best be utilized in the reservoir as a natural propulsive force in the production of oil, as its usual use on the surface is inefficient by comparison. Decline in reservoir pressure normally increases viscosity and, coupled with lack of propulsion, results in a failure of the oil to migrate through the reservoir pore space to the well bore. Failure to maintain reservoir pressure will result in losses of ultimate recovery as high as 75 percent.

The antecedent statements could be called the findings of fact upon which the whole regulatory work of the Arkansas Oil and Gas Commission is based. They have found that the greatest percentage of recoverable oil produced with the least possible decline in reservoir pressure will prevent the need of secondary recovery and repressuring operations, except when these things are made necessary by nature. The success of these regulatory practices is reflected in some performance figures on 11 oil and gas-distillate pools for which the optimum rate of production has been found and fixed.

Lime Pool	*Age in months*	*Total pressure decline, percent*	*Recoverable oil produced, percent*
Atlanta	39	10	29
Big Creek	27	*	3
Buckner	52	20	27
Dorcheat*1	31	21	8
Macedonia*1	8	6	2
Magnolia	49	11	12
McKamie*1	22	3	4
Midway	5½	2	1
Mt. Holly	6	*	3
Schuler-Reynolds	54	6	59
Village	46	4	33

*No pressure change.
*1Gas condensate fields.

Some decline in reservoir pressure is essential to bring about movement of the reservoir content even if this decline is only an operating differential around the well bore. Many factors control this pressure differential and it is not the same for any two pools; also time is required for establishment. Production rates desired having been found and fixed for the pools listed above, it can be expected that percentage values for oil recovered will increase whereas those for pressure decline will remain constant.

Repressuring Old Pools

Outside the jurisdiction of the commission is a number of old pools that may see secondary operations. Some preliminary work has been done toward a study of the possibilities of repressuring the old Smackover field of Ouachita and Union counties by water and gas injection. This field, which was discovered in 1922, has produced almost 400,000,000 bbl. of oil and it is estimated that if repressuring operations prove feasible, an additional 500,000,-

Making a bottom-hole pressure test. The subsurface gauge is lowered through the lubricator on top of the Christmas tree to the bottom of the well bore. A standard gauge is used, raised and lowered by hydromatically controlled wire-line reel powered by 4-hp. gasoline engine, mounted in a specially constructed automotive trailer. These bottom-hole pressure units, of which the Commission operates four, are housed in a laboratory at Magnolia, Arkansas

OPEN "The Second Front" WITH AN OTIS TYPE G (SIDE DOOR) CHOKE

THE *Second Formation* is the Oil Industry's Second Front .... it can be opened through *Dual Completion* with an OTIS Type G (Side Door) Removable Bottom Hole Choke.

By controlling the entrance of fluid into the tubing from either or both pays, the OTIS Type G Choke has greatly simplified the *completing* and the *producing* of two zone wells. Positive in its action, it functions efficiently and economically.

By means of this removable Bottom Hole Choke either formation can be blanked off, or permitted to flow into the tubing. Thus the Type G Choke provides a means *to swab-in* or *circulate-in* both upper and lower zones after packer has been set and the tubing connections permanently tied down.

By the same means, Bottom Hole Pressures can be taken from each zone independently of each other. It is also possible to "kick-off" the annular space should it become "loaded-up," without removing the tubing or breaking the packer seal.

The OTIS Type G Choke can be run and pulled under pressure on an ordinary steel measuring line.

Write for Complete Information and Details

OTIS PRESSURE CONTROL, INC.

DALLAS, TEXAS

Branches: Houston, Texas; Hobbs, New Mexico; New Iberia, Louisiana

Representatives: Otis Eastern Service, Inc., Wellsville, New York; Western Pressure Control, Los Angeles and Bakersfield, California

Export Office: 74 Trinity Place, New York City

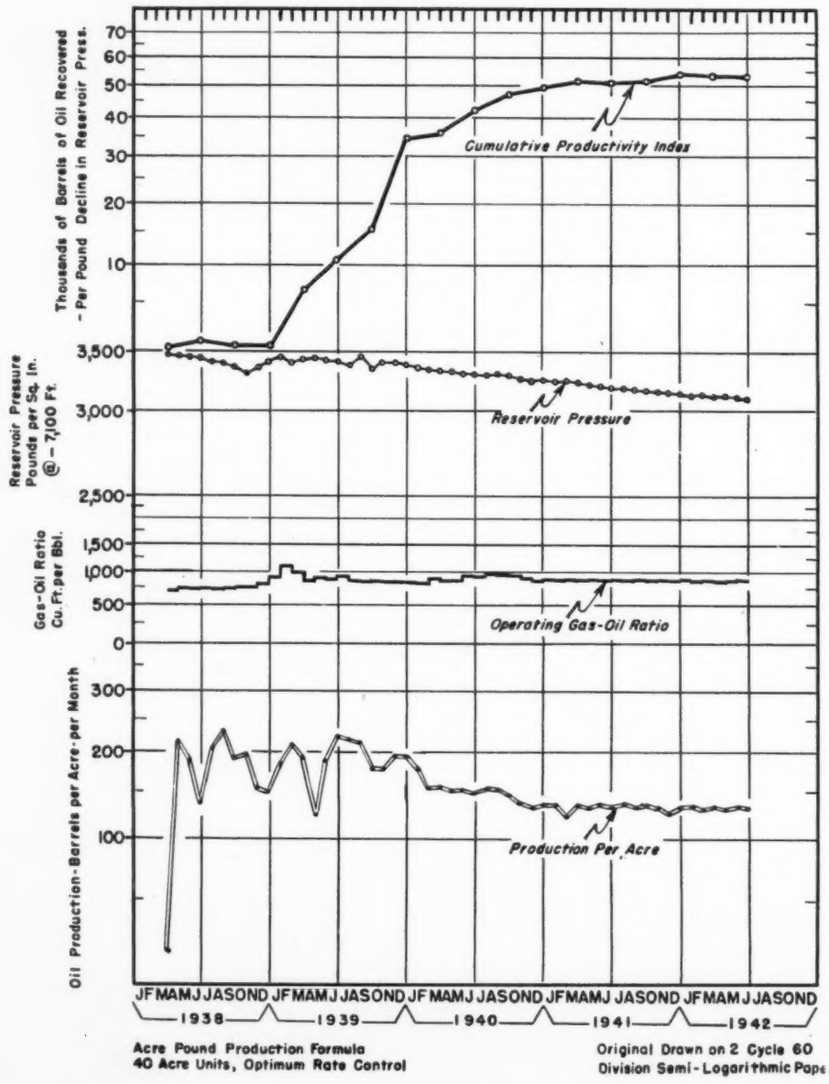
PRESSURE CONTROL · OTIS · SERVICE - EQUIPMENT

000 bbl. of oil can be recovered from the reservoir. The large additional recovery that could be expected is indicated by the fact that the pool was discovered during a time when engineering practices were unknown. It is not impossible that engineering will bring about this recovery of a lost resource. Old pools as well as the new ones are tested by the engineers periodically.

During the early life of an oil or gas pool these necessary tests are made monthly until it can be determined whether the pool is operating under water drive or gas drive conditions. After the pool is typed, production quotas are fixed that will reasonably maintain reservoir pressure in a water-drive pool and not accelerate the natural decline in the gas-driven pool. After this preliminary work is accomplished, usually taking approximately two years due to drilling, tests are made quarterly and production quotas changed according to the results of these tests.

The general taxpayer is not saddled with the expense of maintaining the necessary engineering organization, which is the regulatory personnel in this case. An assessment is made upon the owners of oil and gas to provide the necessary funds for the operation of the department. The entire cost of the operation of the Oil and Gas Commission has averaged slightly less than 1/5 cent for each bbl. of oil produced in the state. This cost includes everything and we believe that it is lower than the per-barrel cost of operating any other such regulatory agency.

Performance chart on an oil pool operating under optimum conditions. Forty-acre spacing; 125 ft. of effective lime section; 18.5 percent porosity; 1500 millidarcys average permeability; 20 percent connate water; 34 percent shrinkage factor; 60 percent recovery factor; original reserves 180 million bbl.; 38° A.P.I. gravity oil; 115 producing wells; gas-oil contact 7245 ft.; 4500 productive acres; optimum rate of production 17,200 bbl. a day; gas-oil ratio 700 cu. ft. to the bbl.; original reservoir pressure 3465 lb. per sq. in.; cumulative drop 363 lb.; oil production to June 1, 22 million bbl.; recovery of 58,000 plus bbl. per lb. drop; cumulative gas production 18 billion cu. ft.; all gas produced being utilized. (Data taken from Factual Data Bulletin No. 30, Arkansas Oil and Gas Commission)


Thousands of Barrels of Oil Recovered - Per Pound Decline in Reservoir Press.
Cumulative Productivity Index
Reservoir Pressure Pounds per Sq. In. @ - 7,100 Ft.
Reservoir Pressure
Gas-Oil Ratio Cu. Ft. per Bbl.
Operating Gas-Oil Ratio
Oil Production-Barrels per Acre-per Month
Production Per Acre
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1938
1939
1940
1941
1942
Acre Pound Production Formula
40 Acre Units, Optimum Rate Control
Original Drawn on 2 Cycle 60 Division Semi-Logarithmic Paper

Commission Work

The work of this engineering body is comprehensive in the exploration, development, and exploitation of the oil and gas resources of the state. Permits are required for the drilling of wells and the actual drilling is supervised by the state engineers to insure adequate protection against subsurface damage as well as surface damage that might be brought about by improper operations. Upon completion of any well, whether a producer or a dry hole, a complete record is required of the formations penetrated, the time required to drill them, and all other pertinent data. In the event a well is non-productive of oil or gas a permit to plug is granted and the plugging operations supervised by an engineer. The real work of the organization begins with the first productive well in a new area. Any new well opening an area to production is tested thoroughly. After cleaning, the well is closed to production and bottom-hole pressures taken. Then the well is opened to production under various rates of flow and bottom-hole pressures taken while the well is flowing. This information is added to from time to time and additional information on the reservoir obtained on other wells as they come into production.

Maps of the area are made immediately and when sufficient wells are completed are contoured to show pressure and the productive horizon. The trend of the field is followed closely as it develops and the behavior of the reservoir pressure and gas-oil ratio under existing production rates checked periodically. This information is supplied to the commission at its meeting and to it is added the experience of the operating companies. From this evidence field rules are promulgated by the commission, fixing a spacing pattern, casing program, and production practice.

The engineers have just completed their tests for the second quarter of 1942 as this is written. Some 18 oil and gas pools were tested for their reservoir pressure, operating gas-oil ratio, and special tests made upon the gas produced with the oil, such as hydrogen sulphide determinations, gasoline content, and specific gravity. This information will be published in a quarter-

THE NEW STAR IS

WYTEFACE "A"!

Once again steel tapes have been improved—and by the same house that has led in measuring developments for the past three decades! This time it's WYTEFACE "A"—a new type of WYTEFACE Tape with *raised* black metal graduations on a crack-proof white surface; easy to read as a newspaper headline; with an uncanny resistance to abrasion that greatly prolongs its useful life. Constant wiping, abrasion with oil and sand, or scraping on the pipe pile have no terrors for this improved steel tape!

WYTEFACE "A" is the result of constant research. Less than thirty years ago all steel tapes were shiny —until K&E developed the well-known Keco finish to provide contrast for the numbers and graduations. In 1935 this same research produced the famous WYTEFACE line, with easy-to-read graduations marked directly on a crack-proof white surface. It is but one logical step to WYTEFACE "A" with its increased resistance to abrasion, designed particularly for oil field service!

There are K&E WYTEFACE "A" Steel Tapes in all sizes and types—in cases or on reels—for every job in the oil industry. You will find them stocked by every leading oil well supply company. Ask your dealer—or write for a catalog.

EST. 1867

KEUFFEL & ESSER CO.

NEW YORK • HOBOKEN, N. J.

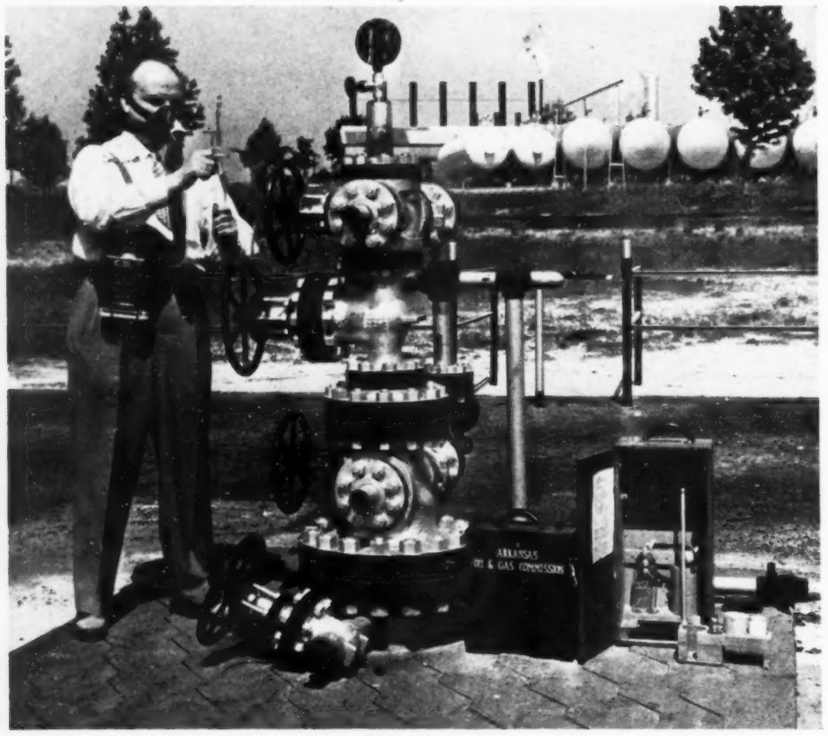
CHICAGO • ST. LOUIS • SAN FRANCISCO • LOS ANGELES • DETROIT • MONTREAL

K&E

WYTEFACE "A"

TRADE MARK

STEEL TAPES



Testing gas for its hydrogen sulphide content. South Arkansas gases have a hydrogen sulphide content of approximately 7 percent by volume. Although this fact makes the gas extremely lethal and explains the gas mask the engineer is wearing, it is also the basis of a new desulphurization industry, wherein commercial sulphur is obtained. After desulphurization, the gas is utilized in the manufacture of aluminum and by a group of war industries

ly bulletin known as "Factual Data Report" and each of the fields tested will be covered in the bulletin. The information given on each field in brief is: location, geology, producing formation, discovery well and date, well spacing, gas-oil contact, water level, effective section, porosity, permeability, connate water, recovery factor, original reserves, gravity of oil, producing wells, producing acreage, current allowable, gas-oil ratio, original reservoir pressure, current reservoir pressure, cumulative pressure drop, cumulative production of oil and gas, and recovery of oil and gas per pound drop in pressure.

These factual data bulletins are published each quarter and are supplied to all parties having an interest in the oil and gas resources of Arkansas. The bulletins are forwarded to the landowners, producers, and others so as to provide sufficient time before each statewide hearing for a complete study of the information the bulletin contains. At the statewide hearing, when production quotas for the next quarter are discussed, both the commission and those in attendance at the hearing are in possession of all the physical facts that should bear upon a rate of production for each reservoir.

There is not much that can be added concerning actual work required in the making of the tests. The field engineering phase of oil regulatory work is, of course, the most interesting. The more laborious routine of office mechanics cannot be pictured.

After the engineers complete their work in the field and prepare their pressure contour maps, the work that remains is that of the auditors and bookkeepers. Each individual well in the state has a ledger sheet in the bookkeeping department titled "Individual Well Status Record". There is a separate ledger for each pool or field made up of these individual well status records. At the top of this ledger sheet is a space for the name of the producer, the lease and well number, the location of the well, date spudded, date completed, drilling time, elevation, top of pay, gas-oil contact, water level, total depth and the casing record, surface, intermediate, and producing, together with the perforating record. Here also are entered the initial test data, such as bottom-hole pressure, gas-oil ratio and first 24-hour oil production, size of choke, casing pressure, tubing pressure, and trap pressure, together with the tubing size and number of feet in use. There is also space for the number of acres upon which the well is located, the effective section in feet, porosity in percent, permeability in millidarcys, shrinkage factor in percent, connate water in percent, recovery factor in percent, and an estimate of the original reserves in barrels under the particular well.

Each month from sworn reports required to be filed by producers of oil in the state and from data gathered by the engineering department there is posted on these individual well status records the behavior of the particular well for that month. This information shows whether the well was flowing, pumping, or on gas-lift, the tubing, casing, and separator pressures, the reservoir pressure, the operating gas-oil ratio in cu. ft., the number of bbl. of water the well made, and the calculated gas production, together with the calculated oil production if there is more than one well on a lease. A record is also kept of the number of days the well produced that month and the cumulative productive well days. A cumulative record of production is also on the same sheet, showing the total amount of water, gas, and oil that the well has produced to date. A monthly record of the gravity of the oil and gas is also noted. Considerable work goes into the keeping of these statistical records but time and again they have proved their value. Companies use the comparative records to guide them in doing recompletion work, whereas the aggregate record is the yardstick of efficiency for the pool.

Other reports are issued by the office force of the commission. In fact, it is they who publish the Factual Data Bulletin. A monthly schedule of allowed production is issued, fixing the amount of oil and gas that each well may produce for that current month, both oil and gas. A monthly statistical bulletin is also supplied to those having an interest in the oil and gas resources of the state. Particularly is this bulletin of use to the federal government. This statistical report covers the operation of oil pipe lines, crude oil refineries, natural gasoline plants, desulphurization plants, gas production disposition, and oil and condensate production disposition within the state. The state is as well informed in matters pertaining to oil and gas as those operating the producing wells.

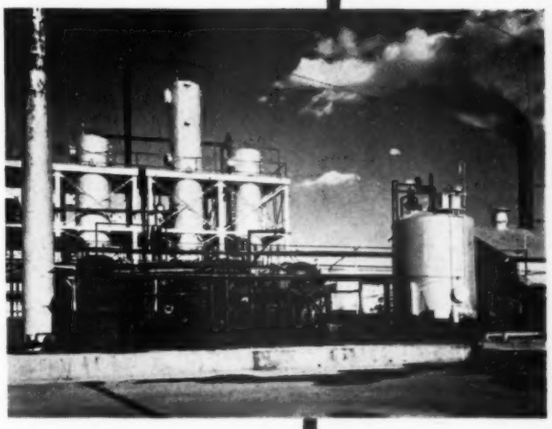
Although it takes a great deal of work, the keeping of many records, the running of innumerable tests, the drawing of charts and maps, law suits, etc., the maintenance of reservoir pressure is all-important. Only by sound petroleum and natural gas engineering practice can this be accomplished.

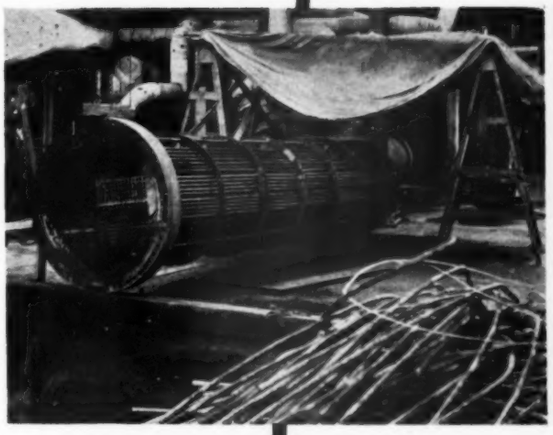
—— ☆ ☆ ☆ ——

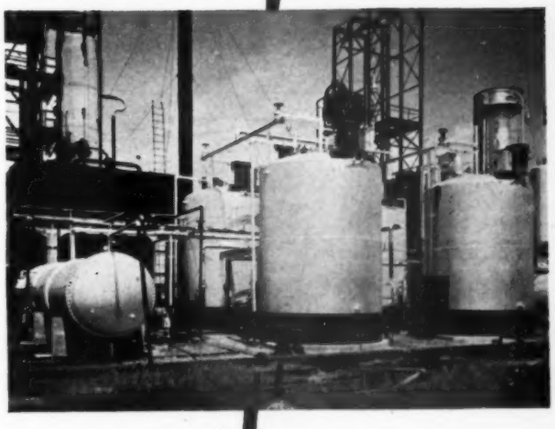
The advantages of

OPTIMUM REFINERY OPERATION

are vital to production for war







And for refiners charging salty crudes, Petreco Electric Desalting assures optimum operation . . . steps up unit capacities, lengthens on-stream time, increases yield, and permits higher operating temperatures.

Without effective salt removal, refinery equipment is certain to suffer from salt ravages . . . Plugging, coking and corrosion take their toll, and lost on-stream time, equipment failures, and excessive maintenance costs climax the damages.

Some refiners have found they can delay salt troubles by curtailing throughput, lowering temperatures and tolerating reduced efficiency. They accept poor operation as the necessary price to be paid for staying on stream.

But this is no time to pamper equipment just to "keep it going"! Especially when the demand for higher octane gasoline is requiring higher refining temperatures and pampering only *delays* salt troubles.

Petreco salt removal is providing optimum refinery operation in many American refineries today. These operations provide our engineers with facts and case histories that should prove interesting to any refinery operator. Petreco engineers are at your service . . . at your convenience . . . at no cost or obligation for preliminary tests and discussions.

PETROLEUM RECTIFYING COMPANY OF CALIFORNIA
GENERAL OFFICES: LOS ANGELES, CALIFORNIA
GULF COAST DIVISION: HOUSTON, TEXAS
EASTERN DIVISION: TOLEDO, OHIO

Representatives in Principal Oil Fields and Refining Centers

PETRECO
DESALTING DEHYDRATING

Submersible Magnetic Strain Gauge

☆ Equipment capable of measuring instantaneous or sustained axial loads—has application in pumping wells

PETROLEUM ENGINEER Exclusive Feature

by E. H. Lamberger, Industry Engineering Department,

and

B. F. Langer, Research Laboratories,

Westinghouse Electric and Manufacturing Company

A MAGNETIC strain gauge has been devised suitable for applications requiring a recording-type, weather-proof, or submersible gauge capable of measuring instantaneous or sustained axial loads. This gauge has operated successfully at the bottom end of a 3500-ft. string of sucker rods pumping an oil well. It is so mounted in a protective, load-carrying case that the electrical response is proportional to the load change in length of a portion of the case that parallels the gauge.

Fig. 1 shows two units disassembled. Fig. 2 shows the relationship between the load and the electrical response measured by a magnetic oscillograph. A complete strain gauge equipment consists of the gauge unit, the control box with filter, the indicating or recording instrument, and a power supply.

The Magnetic Strain Gauge

As the magnetic strain gauge is the basic element of the submersible gauge, a brief description of its construction, principle of operation, and characteristics will be of interest. The magnetic strain gauge may be defined as a device that transforms small displacements into readings on an electrical instrument. It has a wide variety of applications, and many quantities such as stress, force, torque, and acceleration can be measured by means of the displacements that they produce. In the submersible gauge an axial displacement is measured.

The principle on which the gauge operates can be seen from Figs. 3 and 4. E_1 and E_2 are laminated iron cores attached rigidly to frame B (Fig. 3). A is a laminated iron armature attached to frame B′. Frames B and B′ are connected by four leaf springs, C, which allow relative motion between the frames in only one direction and thus act as frictionless guides. When such a motion occurs, the air gap between A and E_1 increases and that between A and E_2 decreases, or vice versa. This changes the reluctance of the magnetic paths in E_1 and E_2 and consequently changes the impedances of the two coils that are wound on them (Fig. 4). The coils on E_1 and E_2 and the adjustable center-tap inductance are connected in a bridge circuit energized by alternating current. When the coils are thrown out of balance, current passes through the rectifier and the instrument on which readings are being taken. For motions up to 0.010 in. the instrument current is proportional to the motion, i.e., the calibration is linear.

The mechanical attachment of the gauge to the test piece is accomplished by means of knife edges visible in Figs. 1 and 3.

The gauge can be moved from one place to another without recalibration. Inaccuracy in the spacing of the mounting holes as great as 1/64 in. can be corrected by adjustment of the armature, A, after the gauge has been mounted.

The outline dimensions are shown in Fig. 3 and a photograph of the gauge is shown in Fig. 5. This picture also

E. H. LAMBERGER

is an application engineer in the petroleum and chemical section of the industry engineering department of Westinghouse—Since 1936 his activities have been mainly directed toward the production of petroleum, assisting in such developments as variable voltage d-c. drilling equipment, a-c. drilling equipment, and all types of oil-well pumping—He was in direct charge for Westinghouse of the Oklahoma City tests on which have been based the new suggested rating standards—This work included development of suitable test devices, laboratory experiments, tests in the field, and subsequent analysis and interpretation of the records that were obtained—A patent application has been allowed to Lamberger and Langer on the submersible gauge for measuring loads in sucker rod strings, one of the devices specially designed for these tests—Lamberger has been with Westinghouse since 1921, the year he graduated from Ohio State University in electrical engineering.

B. F. LANGER

research engineer in the Mechanics Department of the Westinghouse Research Laboratories at East Pittsburgh, Pennsylvania, received his B.A. degree at Stanford University in 1926, and in 1928 his degree as engineer in mechanical engineering—Since that time his work has been mainly associated with the research activities of the Westinghouse company—Langer was awarded the Westinghouse Order of Merit for improving the design of high-speed locomotives by eliminating vibration and sway—In addition to his work for many American railways, Langer in 1939 was employed in an advisory capacity by the French National Railways—He completed his work and left France shortly before the Germans invaded—He has recently co-authored with Lamberger the A.S.M.E. paper, "Calculations of Load and Stroke in Oil Well Pump Rods." The instrument by which measurements were taken for these tests, the magnetic strain gauge, was developed by Langer as an improvement on a basic idea previously used.

REDUCE WEAR *with a* BRIGGS OIL CLARIFIER

ABsorbs Sludge • ADsorbs Acid

Unique and distinct from all others, The Briggs Oil Clarifier utilizes *Fullers Earth* in Patented *molded and bonded porous blocks*. It *cannot* and *will not* wash out, channel or disintegrate due to any action of Hot Oil, Water or Corrosive Acids.

The Patented Fullers Earth Blocks wrapped with multiple layers of Cellulose reduce Engine Wear resulting from dirty oil and corroding acids to the very minimum.

1. By Adsorbing all acids, sludge and resins in the *Molded Fullers Earth Block*.
2. By Absorbing all carbons, dirt and metal particles in *multiple-ply layers* of ribbed *Cellulose*.

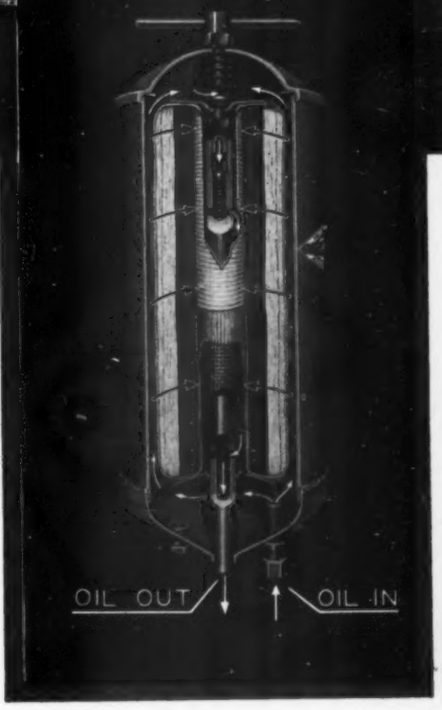
Designed in a perfectly balanced combination of these two well known filtering materials, Fullers Earth and Cellulose, The Briggs Oil Clarifiers keep oil physically clean and chemically pure, thus increasing the life and reducing the wear of vital and now hard-to-get engine parts.

There is a size and type of Briggs Oil Clarifier to fit every Oil Field Engine—from the smallest pumping engine to the largest internal combustion drilling engine.

Your Continental Representative will gladly give you complete details and recommendations.

★ ★ ★

THE CONTINENTAL SUPPLY CO.
General Offices: DALLAS, TEXAS
Foreign Sales Subsidiary
CONTINENTAL EMSCO COMPANY, Inc.
30 Rockefeller Plaza New York City, N. Y.
Representatives:
London Maracaibo Buenos Aires Trinidad



Cut-away section of the Briggs Clarifier showing the construction

30th ANNIVERSARY 1942 CONTINENTAL SUPPLY CO.

CONTINENTAL

SERVING THE OIL AND GAS INDUSTRIES

INVEST IN VICTORY—BUY U. S. WAR BONDS AND STAMPS

shows a control box that contains the variable center tap inductance, calibration resistor, rectifier, milliammeter, and binding posts for connecting to the gauge, power supply, filter, and oscillograph.

A calibrator is available for obtaining a curve of displacement versus electrical response of the magnetic strain gauge shown in Fig. 3. This calibrator consists of a base and a moving platform. The platform is moved by a differential screw arrangement and the amount of its motion is indicated on a dial gauge graduated in 0.0001 in.

Instrument Indicative or Recording

The choice of the instrument on which the readings are taken is determined by the nature of the work being done. For measurements of rapidly varying quantities (periods less than two seconds) an oscillograph is necessary. For lower frequencies or static deflections the oscillograph can be replaced by an indicating meter, a graphic meter, or both. When the oscillograph is used, a filter is advisable to sharpen the record by eliminating the power supply ripples.

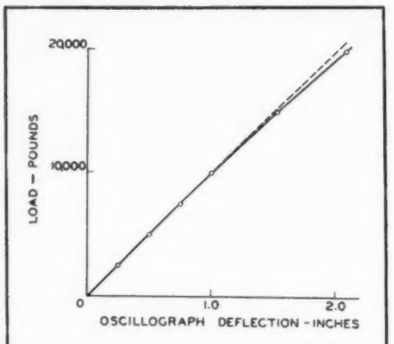


Fig. 2. Curve showing the relationship between the load and the electrical response measured by a magnetic oscillograph

Sensitivity and Power Supply

Under the most favorable conditions the gauge shown in Fig. 3 can give full scale deflection on an indicating instrument, or 4-in. deflection on the film of a magnetic oscillograph for about 0.0003 in. gauge motion. The maximum sensitivity when used with a graphic meter is full scale for 0.001-in. motion. These values are based on a gauge with a maximum motion of 0.010 in. and a power supply of 115 volts, 800 cycles. Under these conditions the gauge requires about 15 volt-amp. at a low power factor. The sensitivity is directly proportional to the impressed voltage and inversely proportional to the total air gap. The air gap mechanically limits the maximum motion. A lower power supply frequency necessitates a lower voltage in order to keep the gauge from overheating. The calibration can be adjusted to the desired value by varying the voltage or adjusting the calibration resistor.

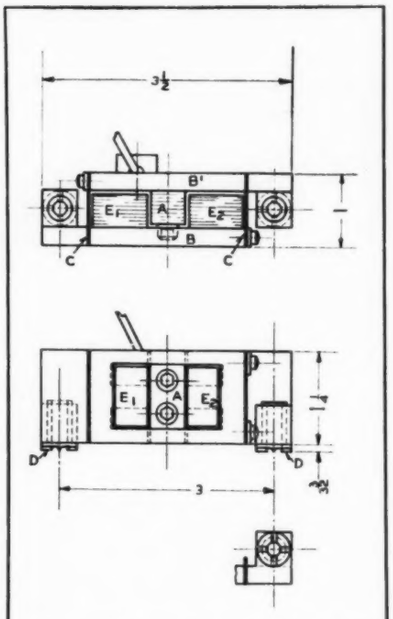
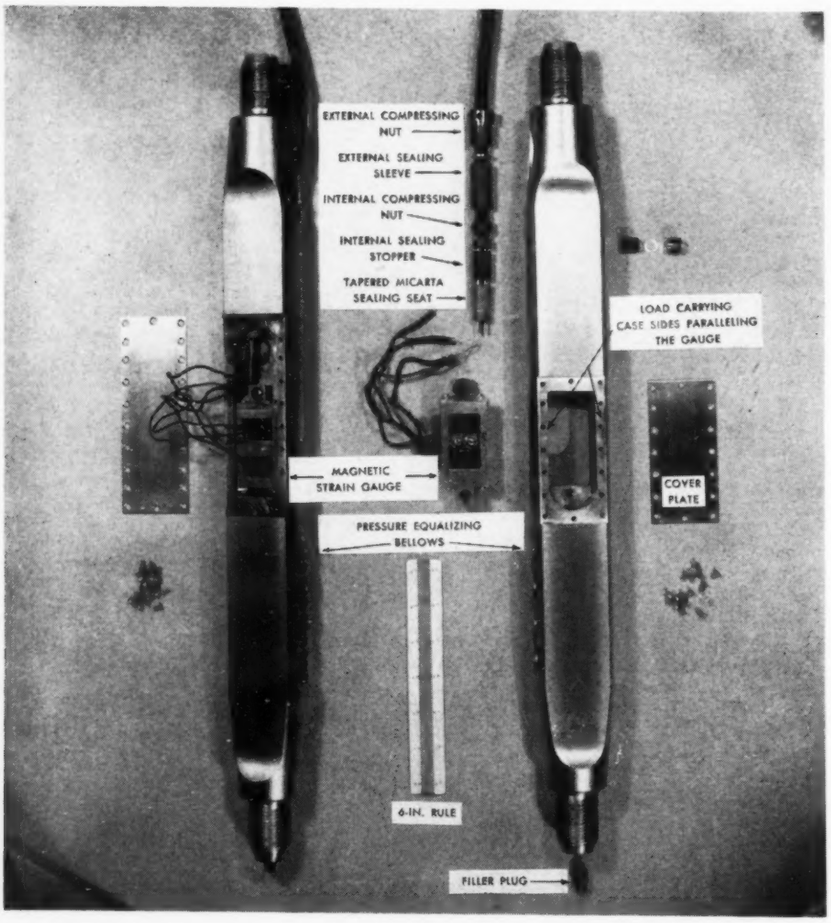


Fig. 3. Schematic drawing of laminated iron cores

Fig. 1. View of a dismantled magnetic strain gauge



Construction of Gauge Case

Two submersible gauges specially developed and used in oil-well pumping tests are shown in Fig. 1. These gauges were designed for operation in oil-well tubing as small as 2½ in. I.D.

The body of the instrument is cut from a single piece of high-grade steel, which is carefully heat-treated after machining and then chromium-plated. A "window" cut through the center provides space for the electric gauge, leaving two load-carrying members forming the sides of the gauge case. The gauge measures the change in length of these paralleling members. Cover plates held with screws and sealed with a cement tested in crude oil, refined oil, and salt water, cover the window after the electric gauge has been installed. The mounting arrangement is such that the gauge centerline

PLASTIC PACKING—

Makes CAMERON Casing Heads, Tubing Heads and Flow Wings SAFELY REPACKABLE UNDER PRESSURE

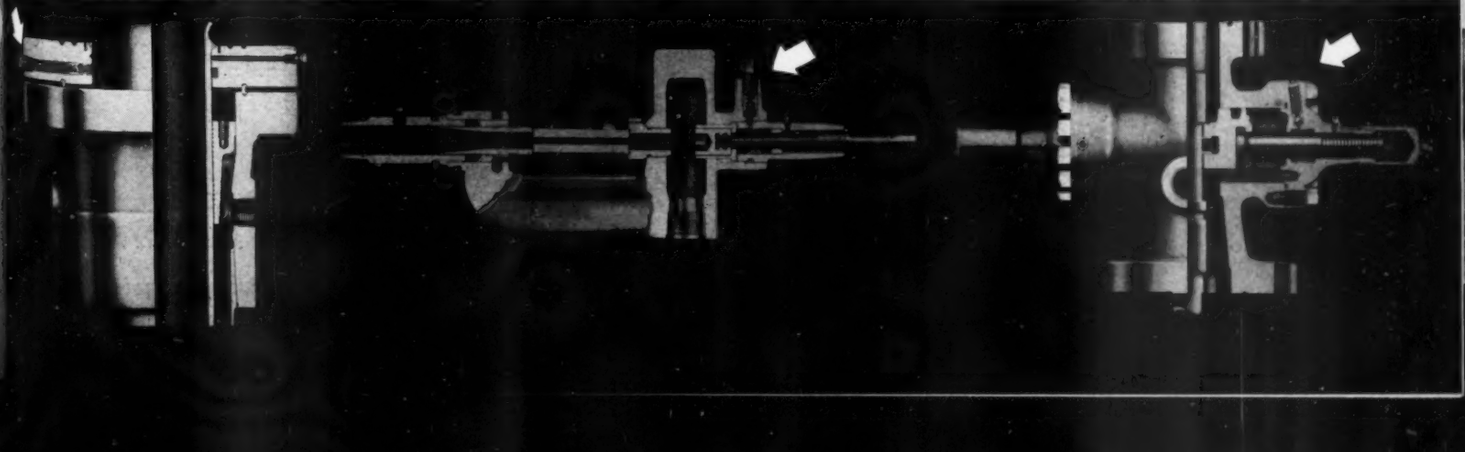
It's not often that a casing head needs repacking, but when casing head packing DOES fail it's mighty handy not to have to kill the well or resort to some risky operation in order to stop the leak. Cameron engineers saw the need for a casing head that could be safely repacked under pressure and developed the use of a non-inflammable plastic packing of shredded asbestos and graphite that could be injected through a small back-pressure valve in a flange above the casing head. The plastic state of the packing permits it to FLOW around the outside of a moulded asbestos seal ring recessed in the inner bore of the flange, thus forcing this ring into sealing engagement with the pipe. Should the seal ever develop a leak, it can be stopped quickly, safely, and easily by simply injecting more plastic.

So successful has this sealing medium proven on Cameron Casing Heads that it has also been employed as a seal around the ram screws on Cameron Ram-Type Tubing Control Heads and around the valve stem on Cameron Flow Wings. (See below.)

Complete details on this exclusive Cameron pressure-control feature will be gladly furnished to interested operators on request.

CAMERON IRON WORKS, INC. • HOUSTON, TEXAS

Export: 74 Trinity Place, New York, N. Y.
California: The Howard Supply Co., Los Angeles
Oklahoma: Paul Edkin, Tulsa
Rocky Mountain: Mountain Sales & Service, Casper, Wyo.



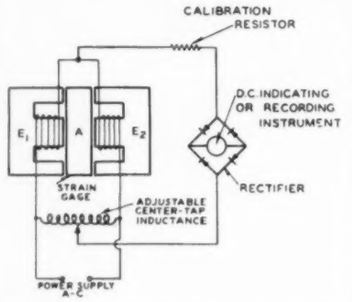


Fig. 4. Schematic drawing of electrical circuit

coincides with the case centerline, thereby giving automatic compensation for slight bending or distortion of the case.

The cable that connects the gauge with the surface instrument enters the gauge and is sealed-off by means of a neoprene bushing that surrounds the cable and is compressed between an internal and external nut. All parts of the cable seals are shown in Fig. 1. The three conductors of the external cable are soldered to three solid conductors that pass through an internal sealing assembly by means of which the internal oil-filled gauge chamber is sealed-off. This seal is accomplished by compressing a neoprene stopper, through which the solid conductors pass, between a tapered micarta stopper and an internal compressing nut. These sealing members are vital as upon them depend two important duties, namely; (a) keeping external liquid from entering the gauge, and (b) preventing loss of insulating oil from the gauge chamber by absorption into the fabric elements of the cable. The entrance of salt water into the gauge chamber would mean grounding, leakage paths, or actual shorting, and loss of a relatively large amount of insulating oil from the gauge chamber would mean crushing of the chamber cover plate onto the gauge, and the probable breaking of cover plate seals.

External pressures may vary due to differences in submersion depths, and internal pressures may vary due to change in internal temperature or gradual loss of internal fluid. The internal and external pressures are automatically equalized, however, by means of the insulating oil and the action of several metallic bellows sealed into the case. Sufficient expanding capacity of bellows is provided to assure pressure equalization even should there be considerable loss of fluid from the gauge chamber. The insulating oil also serves as a medium for equalization of gauge and case temperatures.

Testing and Field Use

The complete gauges were thoroughly tested under pressure in the laboratory during development. During one test a gauge was under pressure for more than two weeks, with maximum pressures of 2500 lb. per sq. in. They were tested in tension at loads as great as 20,000 lb. The calibration was practically linear over the entire range of load, as shown by Fig. 2. The combined characteristics of the gauge, its control, and the recording oscillograph were such that load variations with a frequency up to 18,000 cycles per min. could be measured with a maximum error of 10 percent.

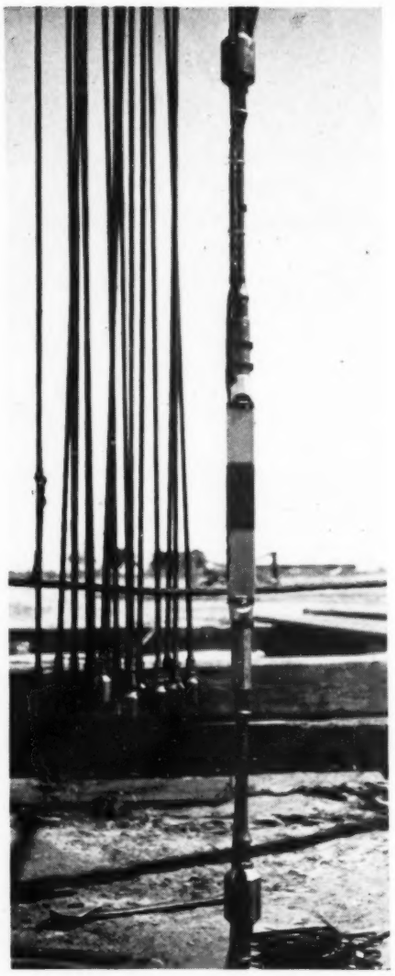
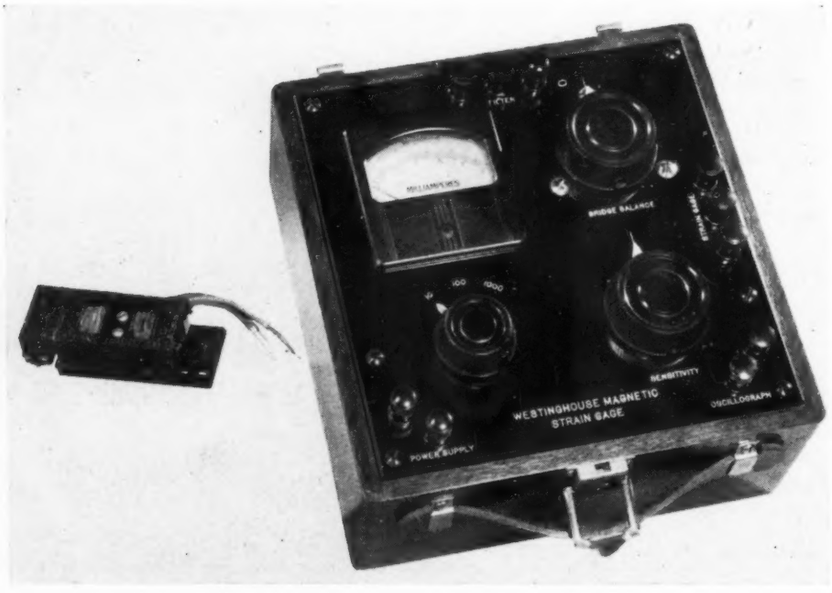


Fig. 6. Magnetic strain gauge in actual service in oil-well pumping tests, ready to be lowered to a depth of 3500 ft.

Fig. 5. Photograph of the gauge and control box that contains the oscillograph



One of the gauges shown in Fig. 1, used in actual service in oil-well pumping tests, was placed in the sucker rod string just above the pump plunger at a depth of 3500 ft. This gauge is shown in Fig. 6 as part of the rod string ready to be lowered into the well. The second gauge was placed in the string approximately 1750 ft. down the hole. These gauges were in the field for six months, were lowered into the well three times, and were in operation in the well for a total period of more than four weeks. They had been sealed before leaving the factory and were returned to the factory at the end of the tests with original seals unbroken. Calibrations at the end of the pumping tests checked original calibrations.

☆ ☆ ☆

Rate of Penetration Record Facilitates Drilling

Exclusive

☆ **Effect of weight, rotating speed, mud pressure, and torque recorded on a single chart during drilling**

by Wallace A. Sawdon

Pacific Coast and Foreign Editor

THE modern rotary driller is a technician. He may hesitate to make such a claim but he has so learned to augment skill and "feel"—gained from long, hard experience—with instrument control of equipment and operation that the drilling of an oil well has become a scientific procedure. The deep wells drilled with efficiency, speed, and safety, frequently in the face of adverse subsurface conditions, constitute ample proof of this fact. Although drilling technique has naturally not yet reached perfection, the continuous advancement in methods, the development of instruments to aid in the best application of those methods and of drilling tools and machinery, and the coöperation of the driller with the petroleum engineer and geologist are aiding in drilling better holes with maximum speed and efficiency.

The control instruments indicating and recording the weight carried on the bit, the mud pressure, rotating speed, and torque have all done much to assist the driller in control of his operations. On several wells drilled in California during the last year these factors have been continuously recorded on a single chart in combination with a record of the rate of penetration. This combined record shows the effect that each of the various factors of weight, rotating speed, mud pressure, and torque has on the speed at which hole is being made. Any change in one or more of these factors will be evident on the rate of penetration curve when any influence is exerted on the performance of the tools in the hole.

Description of Device

The device providing the combined chart consist mainly of a weight indicator, tachometer, mud pressure and torque gauges, and a kelly altimeter. The kelly altimeter shows the feet up on the kelly and is connected to the recorder to give the rate of penetration graph. The recordings of each of the factors are made on an electrically-operated strip chart on which the five records are traced continuously while drilling, as shown in Fig. 1. The recorder is mounted in a steel box with the indicating gauges, the recorder being placed to the right of the gauges so it can be observed most conveniently by the driller. The assembly is installed at the driller's position as shown in Fig. 2.

The primary object of the combined recording is to increase the driller's proficiency by helping him to drill straighter, better hole with greater speed and safety. It provides an automatic record of what he does and shows the effect on the rate of penetration. An experienced driller will frequently employ some method to obtain certain results. Time does not permit a notation of the method, etc., but the chart records this information and preserves it for reference later. Unknown factors sometimes cause unobserved changes while drilling; these show on the chart in their relative value, and their effect on the rate of penetration can then be analyzed.

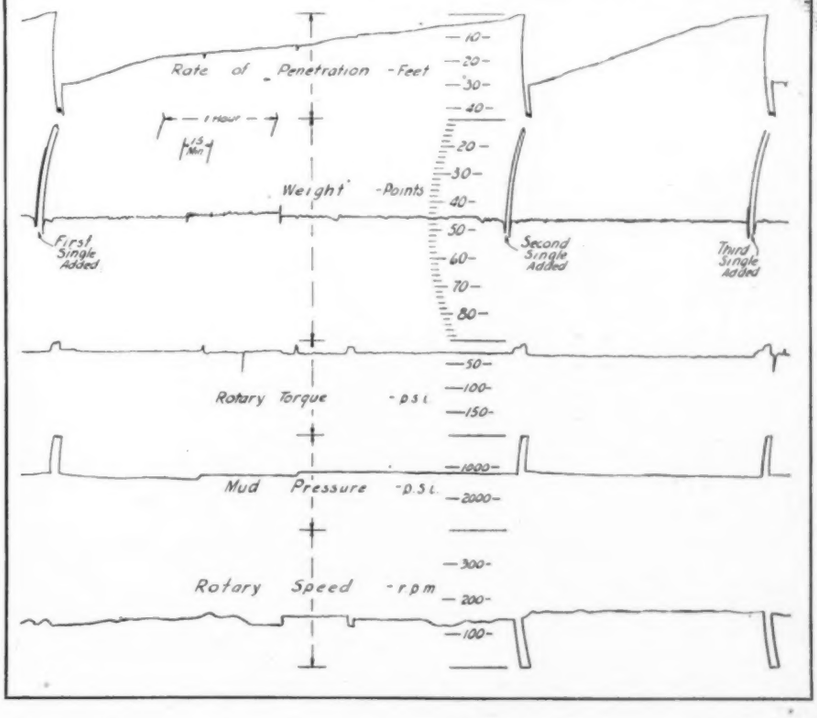
The driller is, of course, primarily interested in the information recorded by the chart while drilling and in what it discloses of performance during the previous tour. The depth of hole, time, and date are noted on the chart at convenient intervals and most drillers carry a bit record along the edge of the strip. When going off tour the record can be turned over to the new driller and from it can be determined the immediate operations until changing conditions warrant different action.

Utility of the Record

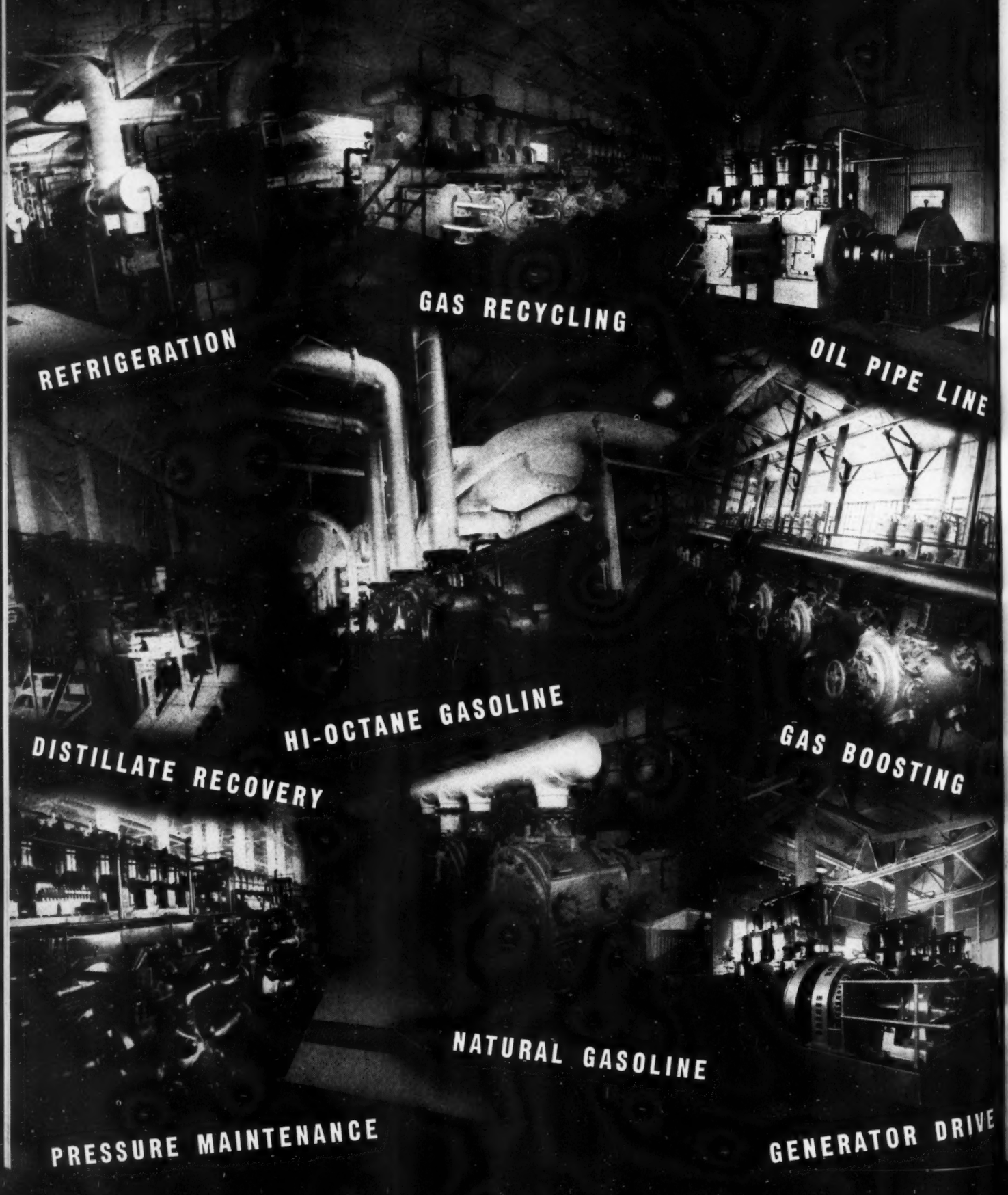
The coördination of drilling operations provided by the chart for greater overall efficiency begins with the driller. The record is passed from driller to driller, the data are available for inspection of the tool pusher and superintendent at any time, and the chart can be used by the engineer and geologist either during the drilling of the well or at a later date. Relative hardness of formations is indicated by the graphs, aiding in correlation work.

The oil industry has been utilizing

Fig. 1. Section of strip chart on which five records are traced continuously



CLARK "ANGLES" SPE



PED INSTALLATION!

Shipped Assembled... Minimum Foundations and Floor Space

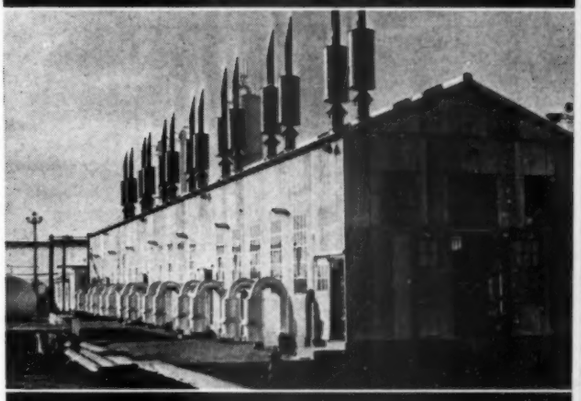
Shipping a CLARK 6-Cylinder Gas-Driven "Angle" fully assembled except for attaching the 4 Compressor Cylinders

TODAY, when speed is the watchword throughout industry, CLARK Gas, Diesel and Steam Driven "Angle" Compressors offer the great advantage of maximum speed of installation. Their compact design permits them to be shipped almost completely assembled, — has reduced more than 50% the size of foundations required, as compared with the older horizontal compressors, — and has greatly reduced area of floor space and size of buildings required. See photos at right.

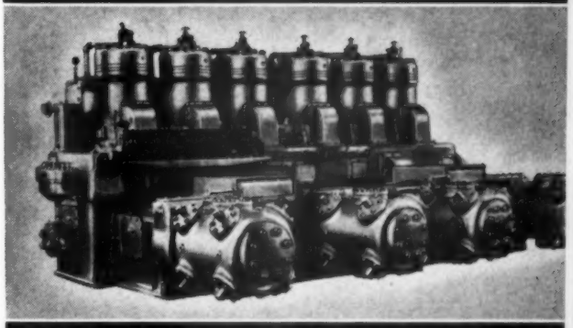
Economy of money as well as time is also highly important today. It is to be noted that the factors mentioned which save time also involve large money savings.

Here are a few of the purposes for which CLARK "Angles" are today in wide demand in the world's industries: Natural Gasoline Recovery, High Octane Gasoline Manufacture, Gas Recycling, Distillate Recovery, Gas Boosting, Oil Refining, Pressure Maintenance, Oil and Gasoline Pipe Line Pumping, Gas Liquefaction, Gas Distribution, Manufacture of Synthetic Ammonia, Synthetic Alcohol, Toluene, Oxygen, Helium, Magnesium, Carbon Dioxide, and other gases and chemicals, Synthetic Rubber Manufacture, Water Flooding, Generator Drive, Refrigeration, Air Compression for glass plants, rock quarries, mines, foundries, machine shops, tank, plane, aluminum and steel plants.

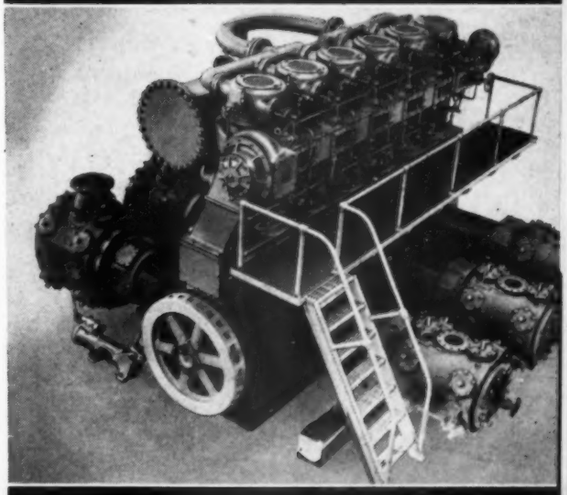
Clark engineers are at your service for consultation and recommendations. Call our nearest office.



This building, only 24 feet wide, houses 7 600 H. P. CLARK "Angle" Compressors, totaling 4,200 H. P.



CLARK 6-Cyl. "Angle" Compressor, gas or Diesel driven. Sizes from 2 to 8 cylinders: Gas-Driven 200 to 1000 H. P.; Diesel Driven, 175 to 700 H. P.



CLARK Model 4 SCRA-14 Steam Engine Driven "Angle" Compressor. Built in 2 to 8-Cyl. Sizes, ranging from 500 to 4,000 H. P.

CLARK BROS. CO., INC., Olean, N.Y. Export offices: 30 Rockefeller Plaza, New York. Domestic Sales Offices and Warehouses: Tulsa, Okla.; Houston, Tex.; Chicago, Ill. (122 S. Michigan Ave.); Boston, Mass. (131 Clarendon St.); Huntington Park, Calif. (5715 Bicket St.); Foreign Offices: 72 Turnmill St., E. C. 1, London; Avda Roque Saenz Pena 832, Buenos Aires.

Affiliated Companies: Dresser Manufacturing Co., Bradford, Pa.; Pacific Pump Works, Huntington Park, Calif.; Bryant Heater Company, Cleveland, Ohio.

CLARK

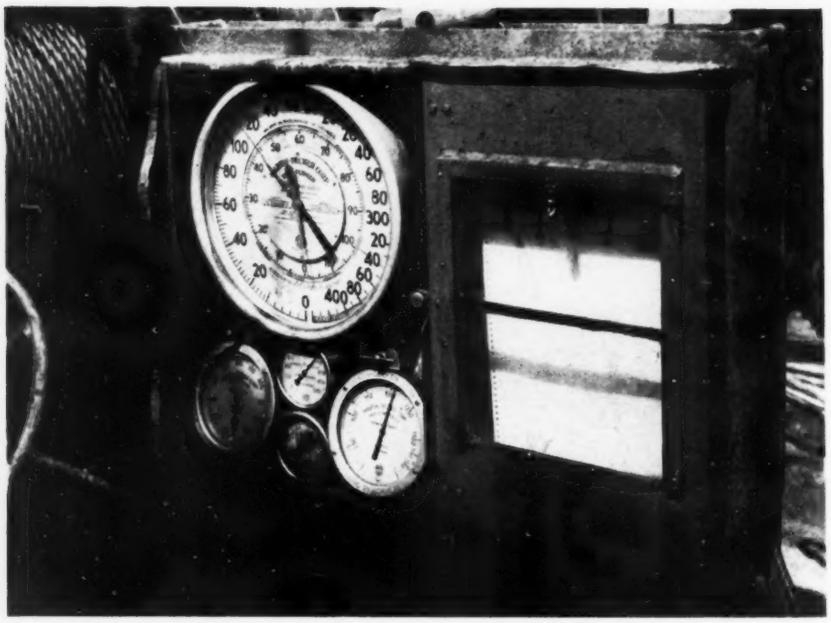


Fig. 2. The combination recorder is installed at the driller's position

permanent records to an increasing extent during the last decade. Such records have been widely applied to obtain greater efficiency in the drilling of subsequent wells and this combination chart offers a definite advancement by assisting in future drilling operations in a field, for it synchronizes the rate of penetration with data on the weight carried on the bit, the rotating speed, mud pressure, and torque—all of which play a part in the speed at which formations are penetrated.

High rotating speeds with light weight carried on the bit have been used effectively in many fields. All formations cannot be drilled with the same rotating speed and weight. The length and size of the drill string and the type of bit being used, the volume and pressure of the circulating fluids, and in some formations the hydraulicking action, will each influence the rotating speed and weight and hence have a decided influence on the rate of penetration. The torque, particularly when using small drill pipe at great depth, must also be given attention and may limit the rotating speed and weight.

Specific Example

The section of chart shown in Fig. 1 is from a well drilling below 9000 ft. with a 7-in. bit on 3-in. drill pipe. In drilling the depth of the first single added after making a round trip, considerable experimental work was done to determine the most effective rotating speed and weight for the formation being drilled at the depth. The weight on the bit and the rotating speed were varied and even the mud pressure changed twice. The torque, although remaining fairly constant, reflected the changes in the other factors when they were made. The drilling speed is shown by the slope of the rate-of-penetration curve and in drilling 30 ft. required a little more than four hours.

When the next single was added the weight on the bit was reduced and held constant at 1½ points below the average used previously; the rotating speed was kept at approximately 165 r.p.m., which was somewhat greater than the irregular speed employed with the first single. The torque remained steady but the mud pressure decreased slightly. The rate-of-penetration-curve maintained a constant slope for about an hour and a half when a hard streak evidently slowed down progress for a few minutes. The time necessary to drill 30 ft. was a little over two hours —or about half the time necessary for the previous single.

The well from which this chart was taken is the second on which the combination recorder* was used in a certain field. Both deep wells were drilled in less time than others of the same company in that field because of considerable experimentation with weight carried on the bit, speed of rotation, and mud pressure. It is comparatively recently that due attention has been given to the mud pump pressure and its effect with different weights and rotating speeds on the speed of drilling and character of hole made. The straightness of hole in vertical wells and the direction control in slant-hole drilling must obviously be given proper consideration and down-hole survey records should be utilized with the drilling performance chart.

*This recorder is known as the Drill-Logger.

The torque curve is probably most widely used as an index of strain put on the drill pipe, but when used in connection with the other graphs will frequently indicate a change in the character of the formation being drilled. In another field where seven points of weight were being carried on the bit the torque developed was so high that it was thought necessary to cut down on the weight. By increasing the pump pressure it was found that the weight could be carried. The rate of penetration chart, however, showed that drilling was not so fast under these conditions and the various factors had to be adjusted in order to maintain the drilling speed. With cause and result thus presented to the driller he can control the different factors relatively and obtain the fastest rate of penetration through the particular formation being drilled.

Various Applications

The various applications of the combined chart are obvious. In slim-hole drilling when close control is more essential than in conventional drilling operations, the data provided by the five graphs should be valuable. When drilling wildcat wells the records can help greatly in subsequent wells. The data can guide in selection of the bit and in determining when the bit should be changed. If it is known that the bit is about to enter a soft formation a round trip may be saved. Whether in a wildcat well or not, a careful opinion of the condition of the bit when changed should be noted on the chart together with other bit data.

As the rate-of-penetration curve when evaluated with the other drilling factors indicates a change in formation, it should aid materially in correlation work. In addition to breaks and markers it should also pick up faults. In one well where it was used a break was indicated when other records showed no indication of such a change. Action was taken on the basis of this information and, although details were not released, it is known that further data were obtained that verified the presence of the break.

The instrument providing the combined chart with simultaneously traced curves showing rate of penetration, weight, rotating speed, torque, and mud pressure is adaptable both to steam and to mechanical rigs powered by gas, gasoline, or butane engines. The torque gauge, however, is not adaptable for use with Diesel engines. When used on "spark-plug" rigs the torque is recorded in inches of vacuum instead of lb. per sq. in. as with a steam rig. In either case the torque gauge indicates the amount of work expended by the engine while turning the rotary table.

☆ ☆ ☆

You can't beat an investment that pays dividends in Human Lives

wyatt's

Automatic Instrument Aids Mud and Well Control

PETROLEUM ENGINEER Exclusive Feature

☆ Weight of drilling mud automatically recorded on 24-hour chart at 2½-minute intervals reveals significant variations of fluid

by John B. Warren, Jr.
President, Warren Automatic Tool Company

THE importance of mud and its control in drilling modern wells has been emphasized on many occasions. The various functions mud and mud control perform, such as preventing cavings of the hole, gas incursions, loss of circulation, and blowouts are now generally known and are accepted facts. Great progress has been made during the last ten years in research and field practice, giving a better understanding of the technical mud problem. It is not the purpose of this article to add or subtract from this knowledge, but rather to show how this knowledge can be, and should be, applied from a practical standpoint not only to reduce substantially the mud cost, but also to minimize many of the difficulties encountered in drilling a well for oil or gas.

Blowout Prevention

The common causes of blowouts are generally known, one being the recycling of gas incursions in the mud until there are enough of these "pockets" in the mud circulating system to reduce the hydrostatic pressure to less than that in the formation. It requires no imagination to realize that when the mud is weighed at periods of an hour or less, the volume of gas in the mud may reach dangerous proportions. An incursion of gas may last—and usually does—for only five or ten minutes and then only for a matter of a few minutes is it really obvious. Blowouts from this cause can be eliminated, but only when a continuous check is made on the weight, which can now be graphically recorded for observation and study. Experience and intelligent use of the record will make it obvious when there are gassy streaks anywhere in the system. The duration and the relative amount of gas in the gassy streaks will be indicated on the record, and thus provide time to take steps to remedy the condition. The continuous record will also be valuable in indicating whether successive occurrences of gas are greater or less than preceding ones, so that treatment can be adjusted accordingly.

In a 5000-ft well each 0.1 lb. per gal. adds or subtracts approximately 26 lb. to the hydrostatic head. It is estimated by the writer that if an accurate check were made of the mud weight on the wells drilling today, 75 percent would show discrepancies of from one to four points from the assumed mud weight. If the orders are to carry 14-lb. mud, and the weight actually is 14 lb., and then a blowout occurs, an abnormal pressure undoubtedly is responsible. That is an unavoidable occurrence that can never be entirely eliminated. If the actual mud weight is 13.8 lb. per gal., however, and the well blows out, then it might be attributed to inaccuracy and carelessness, for with the methods now employed in weighing mud, two points are well within the percentage of error. This condition can be minimized or eliminated.

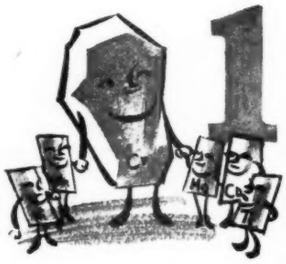
JOHN B. WARREN, JR.,
now a Lieutenant in the United States Navy, was born in Houston, Texas, on July 3, 1912—He attended Virginia Military Institute and subsequently entered Rice Institute from which he was graduated in 1933—Upon graduation he entered the employ of the Humble Oil and Refining Company, in the engineering department, resigning in 1934 to pursue post-graduate work in the University of California, at Berkeley—In 1935 he entered the employ of the Quintana Petroleum Company and was stationed at Refugio, Texas, as a tool-pusher, until 1937—While at Refugio he invented a machine, now called the "Mud-O-Graf", for automatically determining and recording the specific gravity of drilling fluid—In the Fall of 1939, he organized and chartered the Warren Automatic Tool Company, for the marketing of the "Mud-O-Graf" and other oil-field specialties—The company has its headquarters in Houston, Texas.

Manual Control of Mud

Any mud-circulating system on a drilling well is composed of heavy and light streaks. These streaks may vary one or two points to as much as six points in weight. A difference of two points may mean gas incursions or the entrance of salt water and the danger of a blowout. It is particularly desirable, therefore, to keep the weight of the mud in the system as uniform as possible. The methods now employed in sampling mud frequently may never detect the variations, or if they do the variations may not be thoroughly or intelligently understood. For example, if a continuous weight graph is not employed, the mud engineer weighs the mud after an interval of 30 minutes. The small sample he picks up may very easily contain an unrepresentative percentage of sand or cuttings, leading him to believe the mud is over the desired weight; or assuming that the sample is representative, it may well be the very end of a heavy streak. An error may even be made in the manual operation of weighing the sample. In any event, the result is the same. Water is turned into the mud stream and the mud engineer returns to his other duties. For possibly 30 minutes water may be fed into the mud stream when perhaps there was no heavy streak at all, or if there was, it passed by in five minutes. If the resulting light streak causes no trouble, it necessitates at least the addition of weighting material; but if a continuous graphic record were available, water or weighting material could be added, as the conditions required, in economical and safe proportions. The trend of the mud weight could be seen, water added in correct proportion and only so long as it was necessary. Reoccurrence of the weight variations could even be predicted from which could be told whether the treatment was eliminating the condition, and if not, what changes in treatment should be made. Only when the mud engineer knows the exact condition of

Basic Facts about
STAINLESS STEELS

A STAINLESS STEEL PRIMER



STAINLESS STEELS

are corrosion-resistant steels containing at least 12 per cent chromium with or without other alloying elements, such as nickel, manganese, molybdenum, columbium or titanium. They are supplied in a wide range of analyses.

The stainless steels vary in corrosion resistance, workability, wear resistance, and physical properties according to the amount of chromium, carbon and other modifying elements present.

VALUABLE PROPERTIES INCLUDE:

Good corrosion and oxidation resistance . . . varying almost in direct proportion to the amount of chromium present.

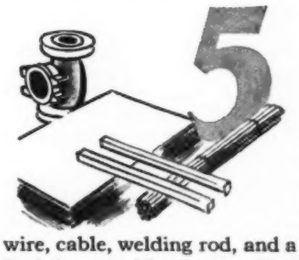
High strength-weight ratio in some cold-rolled types permitting fabrication of strong, light-weight trains, aircraft, and other structures.

MAINTENANCE

of stainless steels is simple. Washing with soap, household cleanser, and water will keep the surface bright and free from surface deposits.

FABRICATION

is accomplished by almost all common methods. They can be machined, spun, deep-drawn, forged, punched, stamped, and otherwise mechanically-worked. They can be welded by all the common welding methods. If the austenitic steels are stabilized with columbium or titanium, and columbium-bearing welding rod is used, no annealing is necessary after welding.



MANY FORMS

are available in the common analyses including sheet, plate, strip, tubing — both seamless and welded — bars, wire, cable, welding rod, and a variety of cold-rolled shapes. Stainless steel is also supplied as foundry castings.

APPLICATIONS

of stainless steel are numerous. Because of their resistance to corrosion and oxidation, as well as their high strength and bright surface, stainless steels have been used in hospitals, chemical plants, oil refineries, railroad trains, aviation equipment, and power plants. In the present emergency, they are available only for those industries participating in war production.

• • •

Although we do not make steel, we have for more than 35 years produced "Electromet" ferro-alloys and metals used in making steel. With the knowledge accumulated from this experience, we are in a position to give impartial advice. If you have a specific problem concerning the manufacture, fabrication, or use of stainless or other alloy steels, consult us without obligation.

Electromet
Trade Mark
Ferro-Alloys & Metals

ELECTRO METALLURGICAL COMPANY
Unit of Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York, N. Y.
In Canada, Electro Metallurgical Company of Canada, Limited, Welland, Ontario.

all the mud in the system and has a record of that condition before him, can the desired properties of the mud be intelligently controlled.

The machine that automatically weighs and records in lb. per gal. the weight of the drilling fluid at 2½ minute intervals on a 24-hour chart, was recently perfected. It was developed after four years of laboratory and field trials and was first placed in commercial operation in August, 1940. The accompanying photograph shows the recording unit in actual operation in the field. One of the charts, with notations of the various operations as they occurred, is shown in Fig. 1. All significant variations in the drilling fluid, even momentary ones, are accurately revealed, with the time at which they occurred, for study and comparison with other operating data.

The chart record is indisputable evidence of exactly what happened. It is a graphic history of the day's operations, and provides the operator with assurance that the most efficient operating schedule was followed.

The machine is entirely automatic in its operation and the only attention required is to change the chart, wind the clock, and fill the recording pen with ink every 24 hours. Excessive cost of mud and slowed-down operations in troublesome wells can easily justify many special measures never before considered, if such measures give promise of reducing only a part of the unusual expenditures hitherto encountered in such cases.

Coming Out of Hole

Many wells get out of control while coming out of the hole. This is due either to "swabbing" or failure to keep the hole full as the pipe is withdrawn. The safest practicable method of detecting whether "swabbing" is taking place, and keeping the hole full at the same time, is to run the "fill up" pump slowly until the hole overflows, shut the pump down, and after a short interval repeat the procedure. An experienced man on a drilling rig can then tell whether the hole is "taking" mud as it should. If the amount of mud that the hole is taking is in correct relationship to the speed with which the drill pipe is being withdrawn, then the hole is not being swabbed and the danger of a blowout is minimized. As simple as this operation appears, a little observation on various rigs will prove that this accepted method is not always followed. The reasons are simple: either the crews purposely let the mud level in the hole go down so that a "dry" string of pipe can be pulled, or the man operating the fill-up pump intends to avoid the trouble of starting and stopping the pump so often. Consequently, the pump is set to run at a speed at which it can be left to run continuously, hence it is not possible to tell with any degree of accuracy where the mud level is, whether the mud is running over, or what proportion of the fluid is going into the hole. The importance of this should be stressed to the men, and in addition some method or check provided to assure carrying out of the proper procedure.

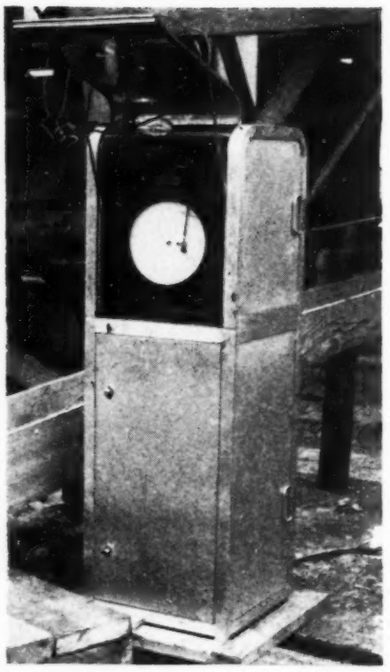
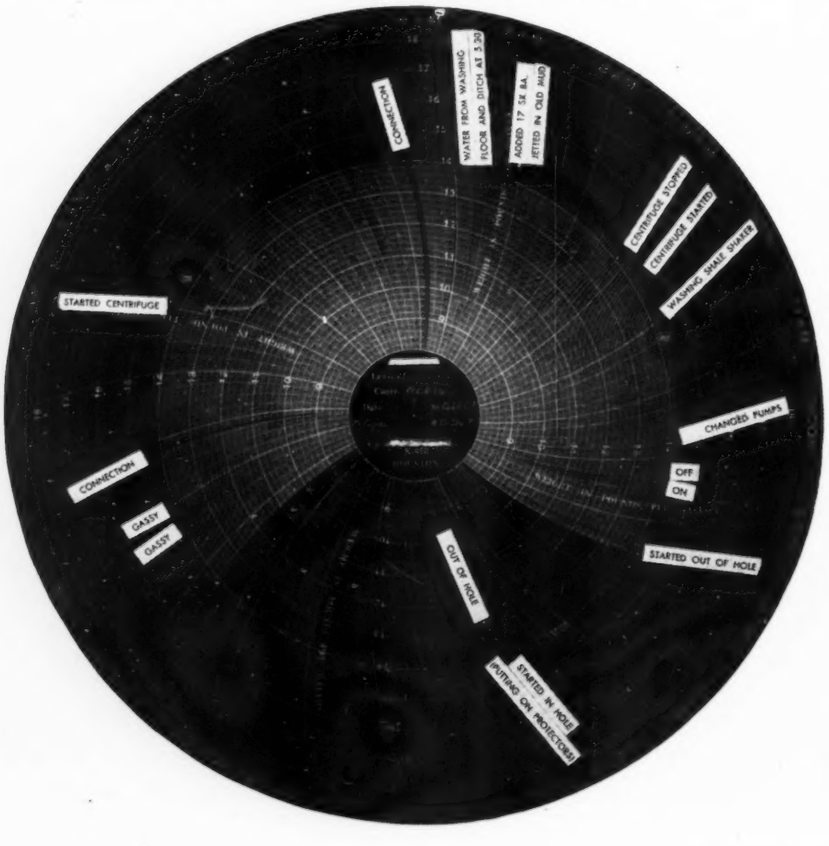


Fig. 2. Recording unit

Fig. 1. Chart with various operations indicated



Conclusion

There is a need for more advanced practices in mud handling and greater education of the man on the rig regarding the importance of accuracy and thoroughness. From observation and study of the methods now used, it is the belief of the writer that a third of the weighting material used is wasted, that three-fourths of the blowouts could be prevented, and that half of the various other troubles could be eliminated by employing the caution and thoroughness any other business would employ when similar expenditures are involved. The oil business of yesterday when the expenditure in drilling a well was recouped in 30 days is no more. Today it may take years to recover the outlay and quite frequently the profits barely yield interest on the capital invested. Too much emphasis cannot therefore be placed on more economical and efficient methods of operation.

☆ ☆ ☆

Gravel-Packing Wells to Increase Production Efficiency

PETROLEUM ENGINEER Exclusive Feature

☆ An evaluation of the present status of gravel-packing and a discussion of what remains to be done to place the practice on a scientific, practicable engineering basis

by Lester C. Uren

Professor of Petroleum Engineering, University of California

THE practice of surrounding with gravel or coarse sand, the perforated liner through the producing formation in an oil or gas well, with the purpose of increasing production efficiency, has come to be known in the petroleum industry as "gravel-packing." This practice has for many years been common in the drilling and equipping of comparatively shallow water wells and the advantages have been recognized by petroleum producers as applicable also to oil and gas wells. The latter, however, being deeper and more complex with respect to their subsurface equipment and completion and operating conditions generally more difficult of control, have required the development of special methods of gravel placement that have engaged the interest of oil producers only during recent years.

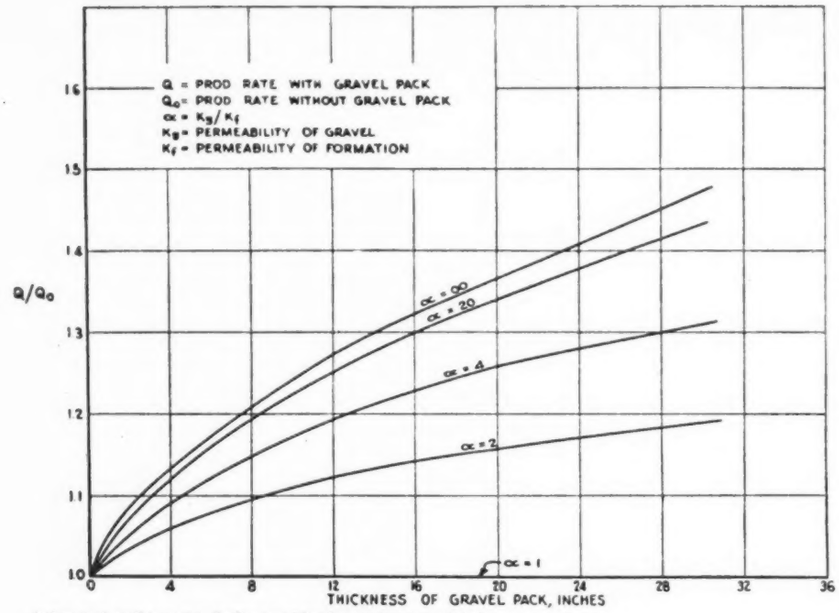
Objectives of gravel-packing. Many advantages are visualized for the well equipped with a gravel-packed liner, all of which tend to increase its production efficiency. When properly placed in the annular space between the wall of the well and the perforated liner, gravel supports the walls of the well, preventing caving of formations against the liner, and serves to restrain sand from unconsolidated and disintegrating strata so that it may not enter the well. More effective screening of sand, possible by this means, diminishes the destructive influence of sand scouring on well equipment, tending to reduce maintenance costs. Equipment repairs and well clean-out operations are less frequent and the well is able to produce for a greater part of the time than would otherwise be the case. The well so protected is therefore capable of maintaining a larger average monthly production rate.

Using gravel to sustain the walls of the well, it is possible to form and maintain a well of larger diameter through the producing formations, without elsewhere increasing the normal diameter of the well or that of the well casing. This larger diameter hole through the producing zone results in increased current rate of production and ultimate production of the well. Ability thus to increase the production efficiency of wells results in increase in the percentage recovery of drainable oil; or, for a given percentage recovery, may permit wider spacing of wells and result in reducing development and operating costs on oil-producing properties.

L. C. UREN

is a leading authority on petroleum practices and the author of several textbooks on petroleum engineering subjects—He received his Bachelor of Science degree from the College of Mining, University of California, in 1911 and has taught courses in mining and petroleum engineering there since 1912, ranking as senior professor in the petroleum division of the department of mining since the inception of the division in 1915—Is a member of the research committee and director of Project No. 28 of the American Petroleum Institute, and a member of the research committees of the American Association of Petroleum Geologists, of the American Institute of Mining and Metallurgical Engineers, and of the National Research Council —He is a member of the professional societies mentioned, and of Sigma Xi, Tau Beta Pi, and Theta Tau honorary fraternities.

Historical development of gravel-packing. For many years, gravel has been placed about screen pipe in shallow, large-diameter water wells, by inserting it at the surface into the annular space between the wall of the well and the pipe, with the expectation that gravity would eventually accumulate most of it at the bottom of the well. Pre-packed gravel screens are not a new device in oil production. The "carborundum screen," which was constructed by compacting crushed carborundum in the annulus between two concentric screens,[40] was used prior to 1920. The writer first proposed the method of gravel-packing by circulation in 1924 and urged its use, both as a means of restraining sand influx and supporting the walls of enlarged well cavities formed within the reservoir rock with the purpose of increasing production efficiency.[35] Later research confirmed the theory that increasing the diameter of the bore of a well results in increased production efficiency.[37,38,39] Scant attention was given to these disclosures by oil producers until, in 1937, The Texas Company became interested in the possibility of controlling sand influx by gravel screening and successfully gravel-packed wells in the California fields by the circulation method. Early efforts were made with gravel that was too coarse and placement techniques were primitive. Even so, results were so profitable that The Texas Company continued development of the method in the field and initiated a program of research, both in its own laboratories and at the California Institute of Technology, to determine the most advantageous conditions that will assure maximum success in gravel-packing



(After K. E. Hill in A.P.I. Drilling and Production Practice, 1941)

Fig. 1. Curves showing relationships existing between thickness and permeability of gravel packs and rate of production of oil wells

operations.[24] Leslie A. Layne of the Layne and Bowler Company,[2] and R. R. Schweitzer of the Layne-Atlantic Company[32] had meanwhile been experimenting with circulation methods of placing gravel about liners, primarily in connection with water well drilling, but also to some extent, in oil wells. Some of Layne's oil-field experiments were made as early as 1931. The Gulf Research Laboratories, Kobe, Incorporated, and the University of California petroleum engineering laboratories have also been supporting research in this field.[8, 9, 13, 16, 19, 41] These activities and publication of results of field applications by The Texas Company,[3, 4, 5] attracted the interest of other oil producers, both in the California and Gulf Coast districts, and during the last few years some hundreds of wells have been equipped with gravel-packed liners.

Several manufacturers of screen pipe, capitalizing on the interest of oil producers in gravel as a screening medium, have revived the principle of the earlier "carborundum screen," by further development of "pre-packed" gravel screen liners, in which gravel is compacted in the annulus between a screen pipe of ordinary type and an outer, concentric screen of sheet metal or wire mesh, and a substantial market for this type of screened liner has been developed in some fields.[30, 31]

Many patents have been issued relating to the art of gravel-packing. A substantial number of these has been acquired by the Texaco Development Corporation, which advertises that it is prepared to license oil producers desiring to use the circulation method of gravel-packing. Leslie A. Layne, Houston, Texas, and the Halliburton Oil Well Cementing Company, Duncan, Oklahoma, have been licensed as service organizations to conduct gravel-packing operations in the interests of oil and gas producers desiring such service.

Thus, an art scarcely five years old in its practical use, has already been accepted as a standard practice in the petroleum industry and it promises to find more extensive application in future years. Technical papers growing out of gravel-packing research projects and others giving the results of field applications, have appeared in considerable numbers during the last few years. Many of the data and the conclusions —particularly those based on field observations—have been conflicting, and the primary purpose of the present article is to review and analyze these conclusions in an effort to evaluate the present status of the gravel-packing art; emphasizing those conclusions that seem sound in theory and proved by well established facts, rejecting those that seem ill-founded, and obtaining so far as may now be possible, a glimpse of what yet remains to be done to place the art of gravel-packing on a scientific, practical engineering basis.

Principles of Gravel Screening

Thus far, oil producers have used gravel screens primarily to restrain influx into the wells of sand formed by disintegration of oil- and gas-producing formations. In some fields, the reservoir sands are so fine-grained and poorly consolidated that it has been found difficult to exclude them from the wells when ordinary types of screen pipe are employed, and in such cases gravel-packing has proved to be effective. To serve this purpose of sand screening, it is essential that the perforated liner be completely enveloped through the producing horizon, with a gravel sheath of suitable thickness; that the perforations in the liner be of such size as completely to exclude all the gravel, and that the gravel particles be of such size and so compacted as to permit only the very smallest sand particles to pass through with the formation fluids into the well. The coarser sand particles must "bridge" over the openings between the gravel particles at or near the sand-gravel interface. These coarse sand particles in turn serve as a barrier for finer sand grains, and thus in time, a combination gravel-sand screen is built up that is stable for the particular hydrodynamic flow conditions obtaining. In this process of bridging sand on gravel, several factors are worthy of careful consideration. Among these are the relative sizes of gravel and sand particles for effective screening, the necessary or desirable thickness of the gravel screen, and the influence of flow velocity and fluid viscosity on the security of the sand bridge.

Size of gravel. Several laboratory research projects have had as their objective, determination of the proper size of gravel to use for effective screening. The results have indicated that the size of the gravel particles must be properly proportioned to the prevailing size of the reservoir sand to be restrained. Sand grains are of assorted sizes and shapes and it is difficult to apply mathematical principles to them. As a matter of practical application, however, it has been found convenient to make a screen analysis of a representative sample of the reservoir sand with the aid of a set of Tyler standard screens, then plotting the results on a cumulative weight percentage graph on semi-logarithmic coördinate paper, and using the size of sand grain corresponding to the 10 percent point on the graph as a reference guide. Laboratory investigations indicate that a stable bridge will frequently form when the size of gravel particles is as much as 13 times the 10 percent sand grain size;[6] but that for dependable screening action, the gravel should preferably be less than 11 times[13] the size of the sand particle corresponding to the 10 percent point on the screen analysis graph. Some authorities recommend a ratio as low as eight.[17, 24]

Complete Gravel Packing Installations

Available through

Leslie A. Layne
Houston, Texas

Halliburton Oil Well
Cementing Company
Duncan, Oklahoma

THE advantages of gravel packing are so great that many wells have been packed in various fields.

Arrangements have been made to provide complete installations on a contract basis through the two companies listed above.

Wherever the sanding up of wells and the sand abrasion of equipment is a problem, this method of protection offers decided advantages. The character of the pack can be readily adapted to the conditions encountered. The need for expensive screens and liners is eliminated.

For complete information including costs of installation write directly to the companies above.

TEXACO DEVELOPMENT CORPORATION

A Subsidiary of The Texas Company

26 Journal Square • Jersey City, N. J.

Early efforts at gravel-packing made use of gravel particles ¼-in. or more in diameter: far too large for efficient screening of most oil sands, and some of the early failures can be traced to this cause.[5] Considerations of the principles outlined above will lead to the use of smaller gravel particles of four to ten mesh (0.185 in. to 0.065 in.) in dealing with most oil sands. The gravel should be screened within narrow size limits: i.e., 6- to 8-mesh; 8- to 10-mesh, etc. Permeability of the gravel envelope is not seriously impaired by using gravel as small as 14-mesh (0.046 in.).

The phenomenon of bridging. Selection of the appropriate gravel size is not as simple a problem as might appear from the rule quoted above, for on careful analysis it is found that other factors than the relative diameters of the sand and gravel particles have a bearing on the effectiveness of the screening action.[24] The carrying capacity of a fluid for sand varies with its velocity and viscosity, and a particular ratio of gravel-sand size, although effective for one oil flowing at a certain velocity, is not satisfactory for another of different viscosity. Generally speaking, the more viscous oils transport sand more effectively than those less so, and thus require a lower gravel-sand size ratio. The same oil, flowing at high velocity, is more effective as a sand-transporting medium than it is when flowing at a lower velocity. If the rate of flow is highly variable, a bridge may form at a certain rate of flow that will be broken if the flow attains a higher rate. There appears to be a certain "threshold" flow velocity for the fluids, at which stability of the bridge formed under a particular set of conditions is destroyed.[24] Yet, the dynamic pressure of the sand grains against the gravel, which is an expression of the rate of flow of the fluids, is also a factor essential to bridging, and too slow a rate of flow may allow the bridge to collapse. Variations in the production rate of a well may thus allow an established bridge to fail, and it must then be reformed before the gravel screen again becomes effective. Studies made with oil as the flow medium do not necessarily give the same results as when gas or water are also present. Heterogeneous mixtures of gas and oil develop higher flow velocities than would be characteristic of the same quantity of oil without the gas, but the effective viscosity of the mixture is less than that of the oil and the sand-carrying capacity appears to be not greatly altered. Oil-water mixtures may emulsify to form fluids of greater viscosity and sand-carrying capacity than that of either ingredient alone.

Use of a simple cumulative percentage graph of the type suggested is not an entirely dependable procedure, for the size distribution of the sand-grain particles is also a factor in determining whether a stable bridge may form. Any number of different cumulative percentage curves may be drawn through a given point on the 10-percent abscissa, and one should give consideration to the symmetry of the screen analysis curve in deciding upon its interpretation. By analysis of the cumulative curve, a type of "frequency curve" may be derived, from which significant criteria may be deduced.[16]

Thickness of gravel envelope for proper screening. Opinions vary concerning the necessary thickness of gravel to insure security against sand infiltration. Some investigators have found that a layer of gravel only five gravel-grain diameters thick is sufficient to form a secure bridge; that if the gravel is of suitable size and properly compacted the sand will not penetrate beyond the outer few layers of gravel.[6,13,17] This assumes, however, that the bridge will be permanent and completely effective. As suggested in the preceding section, there is likely to be occasional readjustment of sand particles with changes in differential pressures and flow velocities, and with each failure of the sand bridge, individual grains—particularly the finer grains—may encroach farther into the gravel envelope. It follows that the thicker the gravel bed, the greater the security against the pore spaces between gravel particles becoming clogged with sand. Sage and Lacey[24] find that the "logarithm of the weight fraction of sand in the gravel bed after a period of flow, varies in linear fashion with the distance from the sand-gravel interface."

Experiments indicate that no gravel screen is completely effective, inasmuch as there will inevitably be some movement of the smallest sand particles through the gravel and into the well with the oil.[24] Indeed, it is probably an advantage to encourage production of a certain amount of this fine "float" sand, for only by so doing may an outer envelope of coarse sand about the gravel envelope be achieved and the clogging influence of the finer material be removed. Material of this character, if it is capable of passing the outer screen of coarse sand, will not lodge in the gravel, for flow velocity and carrying capacity of the fluid increase rapidly as the liner is approached. Under no circumstances, however, should the coarser sand particles be permitted to enter the gravel envelope, for this would create cavities and permit subsidence of the gravel with complete failure of its screening action.

Permeability and porosity of gravel envelopes. In order that the gravel envelope shall restrict flow as little as possible, it is important that its permeability be high. Fortunately, even the smallest sizes of gravel necessary to control sand movement have permeabilities many times that of the reservoir sand.[17] The permeability of closely compacted 8-10 mesh gravel is 1150 darcys; 6-8 mesh gravel, 1900 darcys, and 4-6 mesh gravel, 3700 darcys. The permeability of reservoir sands seldom exceeds 3 darcys. It will be seen that the pressure loss in moving fluids through the gravel envelope is negligible in comparison with that in the reservoir rock, even when the smaller sizes of gravel are used. Experiments have also determined that the sand bridge formed at the sand-gravel interface, though somewhat variable in permeability, is at least 30 times that of the reservoir sand. That is, the permeability of the bridged gravel-pack is at least 30 times what the permeability of the formation about the liner would be if no gravel-pack were used. In one sense, the purpose of gravel-packing is to increase the permeability of the material about the liner and reduce pressure loss and rate of flow of fluids in this critical zone immediately about the wall of the well. It will readily be understood that this is more effectively accomplished in thick-walled gravel envelopes than in thin-walled envelopes. Fluids move at lower velocities at the sand-gravel interface of large-diameter envelopes and their carrying capacity for sand diminishes with the flow velocity.

The porosity of the gravel envelope is of interest as an index of the character of packing of the gravel particles. Rectangular packing of spherical pebbles would result in a gravel mass having a porosity of 47.6 percent, whereas the more compact hexagonal packing of spheres gives a porosity of only 26 percent. As the porosity is diminished, the size of the interstitial pore spaces between grains is markedly reduced and screening action of the gravel becomes more effective.[24] Thus, the screening effect for a particular size of gravel is a function of the porosity.

Large-Diameter Wells

When the gravel envelope fills all the space between the perforated liner and the wall of the well, the producing formations are supported so that they do not cave or disintegrate. This, in itself, is excellent insurance against sand incursion, but in addition, support of the walls of the well cavity within the reservoir rock assures preservation of all the benefits in superior production efficiency that go with large-diameter wells. The writer and his associates have demonstrated these

advantages theoretically and experimentally, and they are now generally accepted by oil producers.[35,36,37,38,39] Under any given operating conditions, the larger the bore of the well through the reservoir rock, the greater will be the rate of production of the well. Large-diameter wells develop larger initial productions, larger productivity indices, and larger potential ratings: a material advantage when proration allotments are based on these factors. Because they offer less resistance to entering fluids and produce with lower gas-oil ratios, and also because their production rate is better sustained, large-diameter wells promise greater ultimate recovery than otherwise similar smaller-diameter wells.

It can be shown by reference to well-established formulas expressing the relationships between the controlling variables in radial flow, that the rate of production of a gravel-packed well increases with the thickness of the gravel envelope and with the ratio of permeability of the sand-bridged gravel-pack to that of the producing formation.[17] Thus, in Fig. 1, it appears that a well with a gravel-pack 8 in. thick and developing a permeability when bridged of 20 times that of the producing formation in a well of normal diameter without the gravel-pack, produces at a rate of approximately 1.2 times that of the ungraveled well. This assumes a 6-in. liner. The rate of increase in production diminishes with increased well diameter and increased permeability, so that there is no great advantage in increasing the ratio of permeability above 25 or 30 and productivity is not appreciably increased by enlarging the well diameter by only a few inches. If gravel-filled well cavities 10 ft. in diameter could be formed, however, as seems possible in unconsolidated or semi-consolidated formations by hydraulic methods, the rate of production of the well would be substantially doubled.[35] Lacey and his associates have also shown in experimental research, that the productivity indices of wells are increased by gravel-packing and that they also increase with well diameter.[24] This conclusion seemingly contradicts opinion expressed by some authorities based on field results, but it is probable that lower-than-normal productivity indices sometimes recorded in gravel-packed wells in the field, are the result of unsuitable methods of placing and washing the gravel.

Development of Gravel-Packing Techniques

Gravel-packed liners are of three types: (1) the conventional type, in which the perforated liner is placed in the well and later gravel is circulated into the annular space about the liner with the aid of a circulating fluid; (2) the gravitational type, in which the gravel is allowed to fall or sink through the well fluid by gravity into an enlarged well cavity and the perforated liner is then driven, rotated, or jetted into the accumulated gravel, and (3) the pre-packed liner, in which the annular space between a perforated liner and an outer concentric screen is filled with gravel in the manufacturer's plant, the pre-packed sections being shipped to the field and connected end-to-end as they are inserted in the well. Each type of gravel-pack has certain advantages and disadvantages and the oil producer must choose the one best adapted to the conditions in the particular well where it is to be used.

Gravel-packing by circulation methods. When gravel is to be placed about a liner in a well by circulation methods, it is usual first to underream or wall-scrape the well throughout the interval in which the gravel is to be placed. If a 5¾-in. O.D. liner is to be used, the reamed hole may be from 16 to 20 in. in diameter, thus leaving a space of 5 in. or more about the liner in which to place the gravel. If the section to be graveled is a long one, centering guides may be placed on the outside of the liner to assure that it is centrally placed in the enlarged hole. Reaming removes all caked mud from the walls of the well through the productive zone and detrital material is all thoroughly circulated out of the well before the gravel is placed. Crude oil or drilling fluid of high colloidity and low viscosity and density is used as a circulating fluid. Thus, the pore spaces of the reservoir rock at the wall of the well are left covered with a very thin mud sheath that is easily disintegrated when the well is brought into production. After the liner is placed in the well, clean, washed, and closely-sized gravel is circulated into the well cavity by adding it at the surface, a little at a time, to a stream of circulating fluid forced down the well under pump pressure. Circulation may be either "normal" or "reversed." In the former system, the fluid and entrained gravel are forced downward through the drill pipe or tubing, which supports the perforated liner at its lower end and extends through or about the liner and concentric therewith, the gravel being deposited in the well cavity about the liner and the circulating fluid returned to the surface through the annular space. In reverse circulation, the descending stream of fluid and entrained gravel passes through the annular space, the gravel is deposited in the well cavity and the fluid returns to the surface through the tubing or drill pipe. Special well equipment in the form of packers, wash pipes, etc., are necessary in either case and surface appliances have been devised for applying pump pressure and feeding gravel in regulated amounts to the descending stream of circulating fluid.* Introduction of gravel must be conducted in such manner as to assure that the annular space about the liner within the productive interval is completely filled and that when in place the gravel envelope shall be substantially uniform in porosity and permeability and free of detrital material and clay accumulations. Under favorable conditions, it has been found possible to place gravel by normal circulation methods in cavities formed around casing, by extrusion through perforations in the walls of the casing.

Normal vs. reversed circulation. Thus far, the industry has preferred the reversed circulation method of gravel placement, using specially prepared, clay-laden drilling fluid as the circulating medium, and the technique of this process is now well developed. The normal circulation method has been used to a limited extent,[6] however, and there is at least one advantage that may be claimed for this method. With reverse circulation, the gravel-laden stream must flow downward along the unprotected wall of the well and probably develops a certain amount of scouring action and erosional effect. This perhaps would not be objectionable, inasmuch as it would aid in removing any residual clay sheath on the wall of the well, but detrital material thus washed from the walls is probably, for the most part, left within the gravel, reducing to the extent that it is present, the permeability and porosity of the gravel envelope. In normal circulation, on the other hand, movement of the circulating fluid is upward through the annular space and any detrital material loosened from the wall of the well is immediately carried upward, free of the accumulating gravel, toward the surface.

Perhaps the ideal gravel-pack would be one in which the gravel is accumulated from the bottom of the well cavity upward by downward settling of the gravel through an ascending stream of fluid moving at such velocity as to wash the gravel particles and develop a sorting action that removes fine material upward with the fluid returning to the surface. To accomplish this, however, requires somewhat more elaborate well equipment and a more precise control of fluid volumes and flow velocities. Reversed circulation has the advantage of comparative simplicity, and the downward move-

*For detailed descriptions of the well equipment and methods of conducting gravel-packing operations, the reader is particularly referred to references 6, 10, 11, 12, 15, 21, 22, 25, 26, 28, 29, and 32.

ment of fluid and gravel into the well cavity assists in more thorough compaction of the gravel particles.

Drilling fluid vs. oil as the circulating medium. Although most gravel-packing operations have thus far used clay-laden drilling fluid as the circulating medium, there is good evidence indicating that crude oil would be preferable under most conditions. Use of clay-laden fluid leaves a mud sheath on the wall of the well and gelled clay in the pore spaces of the gravel envelope that, if allowed to remain, may seriously restrict later productivity of the well. It is believed that in cases in which gravel-packed wells have had productivity indices lower than offset wells, clay accumulations have not been adequately removed. The remedy for this condition lies in a thorough washing of the gravel envelope through the liner perforations, after placement of the gravel is complete. In many field installations this has been imperfectly done; yet, carefully conducted tests in field-scale laboratory apparatus have indicated that all gelled clay can be washed from the gravel and even the toughest wall sheaths can be disintegrated by washing through the liner with sufficient pressure and volume of washing fluid. Much may be accomplished also, in preventing formation of thick wall sheaths, by proper conditioning of the fluid used in underreaming and gravel placement. Use of lime muds that can later be disintegrated by treatment with inhibited acid, is also a promising method.

When conditions permit of its use, oil would appear to be the ideal placement medium. With oil, there need be no clay accumulations to deal with and the walls of the well would be left oil-wet and capable of developing maximum permeability for subsequent production. Laboratory studies have confirmed the expectation that gravel envelopes so placed have superior productive capacity in comparison with similar envelopes in which clay-laden fluid has been used as the placement medium.[8, 9] Use of oil, however, is somewhat more difficult from a practical standpoint and may occasion no little inconvenience and expense in changing over from the usual clay fluid employed in drilling operations. If the formation pressure is high, the opposing pressure developed by the static head of the oil column in the well might not be sufficient to prevent a blowout unless special precautions of a mechanical nature are taken at the wellhead. On the other hand, in graveling low-pressure, partially depleted, or highly permeable reservoir strata, the oil may drain into them from the well so rapidly that it is difficult or impossible to maintain circulation. Some producers are reluctant to use oil in the belief that in unconsolidated strata the wall of the hole is more likely to cave without the support that the clay sheath gives. Experimental studies have shown, however, that there is little tendency for such formations to cave if pressure within the well is maintained equal to or above that in the reservoir rock. If oil is used as the circulating medium and there is any choice among available oils, a heavy, viscous oil is preferable. Usually the crude oil produced in the field must be used for economic reasons; but the use of refined fractions of crude petroleum having the desirable properties highly developed has been proposed.

Gravitational placement method. Depositing gravel in well cavities by gravitational methods is primitive and may be expected to give satisfactory results only when the well is comparatively shallow, the productive section of hole to be graveled of no great thickness, and the walls of the well sufficiently stable so that they do not cave readily. In the Loma Novia field, Texas, about 200 wells have been successfully gravel-packed by this method.[15] This field is partially depleted and is now under gas drive, but sand and clay incursion into the wells continues to be troublesome, requiring frequent pump repair and clean-out operations. Using cable tools, the wells are thoroughly cleaned out, a cavity formed within the reservoir rock by mechanical means, and sufficient gravel poured down inside the casing from the surface to fill the well cavity. The perforated liner, equipped with a special shoe, is then lowered into the well and driven into the gravel-filled cavity. On resuming production, the average well shows an intial increase in production of 143 percent and a "settled" increase of 93 percent. The cost averages $600 per well. This method could hardly be expected to be successful in thick-bedded producing formations, for there is no means of maintaining the liner in the center of the hole while driving it through the gravel.

Pre-packed liners. Lacking experience and proper equipment for gravel-packing by circulation methods, many producers have resorted to the use of pre-packed liners. These are available from several manufacturers and vary somewhat in construction and design.[30] In each case, the interior liner is of the regulation slotted type, with slots of such size as to prevent any movement of gravel particles through them. Concentric with the liner and supported on it by spacing guides, is an outer screen constructed of either stout woven wire, perforated sheet metal, or light-weight slotted screen pipe. Gravel of appropriate size is compacted within the annular space between the slotted liner and the outer screen. Usually the gravel sheath is about ½ in. to ¾ in. thick and is compacted by special methods involving vibration or water action, which insure minimum porosity. Pre-packed liners in lengths up to 40 ft., are prepared in the manufacturer's plant and shipped to the field, where the sections are coupled by collared joints like ordinary casing as they are inserted into the well. They are heavy and must be carefully handled to avoid damage to the outer screen. The casing through which they are run must have an inner diameter at least 1 in. larger than the outside diameter of the outer screen. Thus, a 5¾-in. gravel-packed liner, as prepared by one manufacturer, has an overall diameter of 7¼ in. and requires use of a well casing at least 8⅝ in. in size.

Relative advantages of pre-packed liners and gravel envelopes placed by circulation methods. Pre-packed liners have the advantage that they require no special equipment or skill on the part of the operator in placing them in the well. They lend themselves to ordinary programs of well casing and are especially useful in dealing with multi-zone situations of considerable thickness. Though they provide but a minimum thickness of gravel about the liner for successful screening, it is assured that this envelope is continuous and of uniform permeability and porosity. The gravel is positively in place all around the liner and there are no open channels through which sand movement may occur.

An important criticism of the pre-packed screen is that it provides none of the advantages that result from preservation of the larger diameter hole. It uses a liner smaller than could be inserted in a hole of the size that must be drilled to receive it, and provides no support for the walls. Space necessarily left in the hole around the liner permits the formation to close in about it. When this occurs, due to structural weakness of the outer screen, the liner becomes "frozen" to the formation and cannot later be removed. One variety of pre-packed liner in which the outer screen is constructed of drillable metal can be removed from the well after the walls close in about it, but the screen is destroyed in retrieving it. The wire screen or thin-walled sheet metal of which the outer screen is composed, is likely to become abraded by contact with the casing and wall of the well during insertion, and subsequently may rapidly deteriorate by corrosion. Scraping against the mud sheath on the wall of the well during insertion, the openings in the outer screen become clogged

Research....

KEYSTONE OF

PITTSBURGH-DES MOINES' PROGRESS

The program of engineering research maintained by the Pittsburgh-Des Moines Steel Company over the years, now culminates in the establishment of a Multiple Fellowship on Chemical Containers and Storage at the Mellon Institute of Industrial Research.

Utilizing the unlimited scientific resources of the Institute, the Fellowship will conduct research on the problems connected with bulk storage of chemical substances, including water, oils, and gases.

At the present time, the Fellowship is working on vital problems connected with the storage of chemicals in the synthetic rubber industry, including butadiene, styrene, acrylonitrile, and isobutylene.

The general research conducted by the Pittsburgh-Des Moines Chemical Storage Fellowship will develop much new chemical and physical data available to our clients, in the form of reports and recommendations as to the most suitable types of containers, construction, temperatures, pressures, linings and coatings for the protection of the container and the substances for which bulk storage facilities are desired.

PITTSBURGH • DES MOINES STEEL CO.

PITTSBURGH, PA., 3404 NEVILLE ISLAND—DES MOINES, IOWA, 903 TUTTLE STREET

NEW YORK, ROOM 983, 270 BROADWAY • CHICAGO, 1208 FIRST NATIONAL BANK BUILDING

DALLAS, 1207 PRAETORIAN BUILDING • SAN FRANCISCO, 609 RIALTO BUILDING

SEATTLE, 1112 EIGHTH AVENUE, SOUTH

with clay that may be removed only imperfectly by washing through the gravel bed. Though the pre-packed liner itself may be pressure-washed from within, so that it is free of accumulated clay—at least opposite the liner perforations—experiments have shown that it is very difficult or impossible to remove the mud sheath on the wall of the well by washing through the perforations and gravel bed. Mud may be washed from the walls by circulation through a wash-pipe in the liner and loosened by "wall scratchers" mounted on the outside of the liner. Once the walls have closed in about the liner, however, all washing must be through the perforations of the liner, the gravel bed, and outer screen. Shale accumulations against the outer screen may effectively seal-off portions of the reservoir rock. The closed apertures of the outer screen then restrict flow of fluids to but a portion of the gravel channels provided within.

A gravel-pack properly designed and placed by circulation methods, has none of these disadvantages. A circulated pack provides a thicker gravel envelope that affords better screening action, with less possibility of its pore spaces becoming clogged by sand incursion. The walls of the well are positively supported so that they cannot cave or disintegrate. The superior production capacity of the large-diameter hole is therefore preserved throughout the life of the well. Although the well cavity through the reservoir rock may be large, the diameter of the hole through the overlying formations may be small. The advantages gained by use of the circulated gravel-pack may thus be combined with the economies afforded by "slim-hole" drilling. Smaller and less expensive well casings may be used.

Oil and gas may flow directly from the producing formation through a gravel-pack placed by circulation methods, without contending with the restricting and clogging action of an outer, secondary screen. The circulated pack supports the liner and affords protection against vibration damage and column failure when it rests on the bottom of the well. A liner enclosed in a circulated pack may be removed without damage at a later date by inexpensive methods of "washing over" or circulating-out the gravel. Cement plugging, deepening, or other well repair operations are thus facilitated. In time of steel scarcity, as at present, the circulated gravel-pack is especially attractive, inasmuch as it requires a minimum of steel and permits of using old liners or perforated second-hand casing as the gravel-supporting medium, yet providing maximum protection against sand incursion.

Economics of Gravel-Packing

There are cost data and oil recovery records obtained from operations in several California fields that demonstrate important economic advantages for wells packed with gravel by the reversed-circulation method.[3, 5] Additional costs of gravel-packing, in comparison with the cost of conventional completion methods, range from $1050 to $3250 per well, varying with the depth and thickness of the producing formation to be graveled and the diameter of the well and liner. The higher figure is for wells in the Wilmington field, California, where the average thickness of the zone graveled is 400 ft., 5¾-in. liners are used and wells are wall-scraped to about 16 in. A large part of the cost is represented by the cost of rig time, which is included in the figures quoted at the rate of $350 per day. In the case of the Wilmington field, the cost of five days rig time, or $1750, is included. The material and equipment cost does not exceed $1500 in any case. Gravel can be purchased in this locality for $6 per ton.

The figures given are for early operations (prior to October, 1938) and it is probable that with methods and equipment better standardized the cost will not now ordinarily exceed $2500. Much may be accomplished in reduction of costs by reducing the time spent in reaming and graveling operations. This can be achieved by providing proper equipment and employing a skilled service organization to do the work. Services of an organization that supplies all special surface equipment and assumes responsibility for rapid and proper placement of the gravel, are available in the Wilmington field for $500 per well.

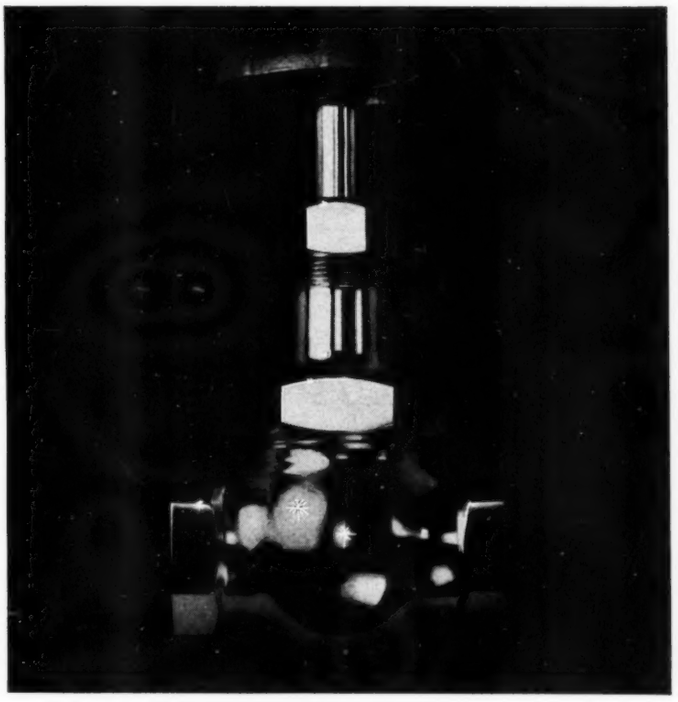
Due to greater rates of production for graveled wells, less "down time" and reduced well and equipment repair expense, unit maintenance costs for graveled wells are found to range from one-half to less than one-tenth the cost of wells completed by conventional methods during comparable production periods. Savings of as much as 7 cents per bbl. of production are realized on some properties in the San Joaquin Valley and Los Angeles Basin fields of California. These savings were realized while conforming with curtailed production rates imposed by proration. Had the wells been permitted to produce at their full potential rate, a much greater advantage might have been shown for the gravel-packed wells. Wells repay the cost of gravel-packing in increased production and reduced maintenance costs in but a few months in some cases.

Wells equipped with pre-packed liners are said to cost somewhat more than wells graveled by circulation methods.[34] An average size of pre-packed liner as prepared by one manufacturer, costs $5.40 per linear foot. Of this, $2.40 is the cost of the liner and $3 the cost of the gravel wrapping and outer screen. To this must be added extra costs in shipping and handling, washing, well conditioning, rig time, etc. If one were to take into account the extra cost of the larger size water string that must be used to accommodate the additional diameter of the pre-packed liner (for a given size of liner) the economic advantage of the circulated type of gravel-pack over the pre-pack would be more apparent.

Some operators believe that they are not justified in meeting the extra cost of gravel-packing because proration restrictions do not permit of taking full advantage of the greater productive capacity that gravel-packing confers. Field results show, however, that when sand conditions are troublesome, reduction in maintenance expense alone will justify the expenditure; furthermore, proration restrictions are not permanent and may be relaxed during the years just ahead. If a well may profitably be graveled later, it may better be done at once so that it may profit by its superior production efficiency throughout as long a period as possible.

Opportunities for Future Improvement

The art of gravel-packing, as applied to oil and gas wells, is as yet underdeveloped. Much progress has been made during the last few years through laboratory research and field development, but more of this type of work yet remains to be done before the ultimate possibilities of this method of improving production efficiency may be visualized. Field methods of installing gravel-packs by the circulation methods must be perfected before an installation of this kind may be undertaken with the assurance that it will be carried through with precision and with the certainty that the gravel envelope will completely surround the liner, filling the entire well cavity about it with a mass of properly-sized gravel of uniform permeability and porosity, the interstices of which are entirely free of clay and accumulated detrital material. Much may be accomplished in perfecting the technique of this work, by entrusting as much of it as possible to a skilled and properly equipped service organization. The average operator of an oil-producing property is not sufficiently skilled and does not possess the necessary equipment to undertake this work efficiently



★
READING-PRATT & CADY
VALVES FOR
THE OIL INDUSTRY
★

LOYALTY IS NOT TAGGED WITH THE PRICE OF BRASS

These are the UNITED STATES.

Of course we differ among ourselves. But the world has learned, again, that these are family matters—marks of energy that, upon attack, crystallize to dynamic unity.

Men who battled the devil with words from the pulpit now fight him with machine guns from the ranks. Fingers that were trained for gossamer express their loyalty on the assembly lines of huge bombers that will blast America's enemies from security.

And it is no less indication of the spirit today that, as forge and press thunder their answer to the call to war, men in industry cease to demand that priority deliver *anything* for peace that tools can fashion into arms. In that same spirit, too, men no longer clamor that vitals such as nickel, chromium, and brass be delivered for civilian use.

Certainly, substitutes for products of proved economy work hardship and add to the cost of industry. And that may be particularly true when applied to valves.

But, Americans already prove that they don't tag their loyalty with the price of Brass!

READING-PRATT & CADY

MANUFACTURERS OF R *AND* P&C CO. *VALVES AND FITTINGS*

Reading, Pa., Atlanta, Boston, Chicago, Houston,
Los Angeles, New York, Philadelphia, Pittsburgh, San Francisco

ACCO

A Division of AMERICAN CHAIN & CABLE COMPANY, INC. *Bridgeport, Conn.*

and with the assurance that it will be successfully completed.

In the field, more work should be done in perfecting methods of removing gelled clay from the recesses of the gravel and from the walls of the well, so that maximum productivity may be attained. Chemical methods of treatment of gravel-packs and wall sheaths, as a means of removing accumulated clay and detrital material, offer promise. Methods of gravel placement involving use of oil as a circulating medium should be explored. Methods of forming larger well cavities at lower cost are needed. Use of the hydraulic method offers promise in this direction. Further field studies of the radius of drainage influence of large-diameter gravel-packed wells, and of ultimate recoveries obtainable from them, are needed. It may well be that important savings in development and operating expense through wider spacing of wells, will be possible by this means. Further study of the normal circulation methods of gravel placement is justified. Methods of placing gravel in well cavities in highly permeable or partially depleted, low-pressure formations should be developed. Methods of economically removing gravel and liners from gravel-packed wells to facilitate deepening or plugging operations should be studied. Possible systems of effectively graveling multi-zone wells, perhaps by methods involving placement of gravel through perforations in the casing or liner, are promising and should be investigated. Methods of successfully conducting gravel-packing operations by circulation in off-vertical wells should be investigated. Advantages of gravel-packing injection wells in gas-drive, water-flooding, salt-water disposal, and "distillate field" exploitation projects, offer interesting possibilities for future study.

Improved production efficiency in many directions may be expected to follow upon further development of gravel-packing technique, and the economies thus gained promise amply to justify the cost of the additional research and development work necessary.

Bibliography

1. "Gravel Packing 6400-ft. Southern Louisiana Flowing Wells," by F. N. Brasher, *Oil Weekly*, April 10, 1939, pp. 22-24.
2. "Gravel Packing Oil Wells in the Gulf Coast Fields," by M. L. Cashion and F. B. Markle, *Oil and Gas Journal*, April 4, 1940, p. 48. (A.P.I. paper.)
3. "Economics of Gravel Packing in California," by W. A. Clark. *A.P.I. Drilling and Production Practice*, 1939, pp. 327-332.
4. "Developments in Gravel Packing," by W. A. Clark, *The Petroleum Engineer*, Mid-Year issue, 1939, p. 36.
5. "A Resumé of the Application of Gravel Packing to Oil Wells in California," by W. A. Clark. *A.I.M.E. Petroleum Development and Technology*, 1940, pp. 15-24. See also, *Petroleum Technology*, August, 1939.
6. "Some Considerations in the Selection and Installation of Gravel Pack for Oil Wells," by C. J. Coberly and E. M. Wagner. *A.I.M.E. Petroleum Technology*, August, 1938, pp. 1-20. Technical Publication 960.
7. "Gravel Packing," by H. R. Collins. *The Cementer*, Halliburton Oil Well Cementing Company, July-December, 1938, p. 16.
8. "A Study of the Fluid Media Used in Placing Gravel About Screen Pipe in Oil Wells," by E. G. Dobson and T. H. Benton. Senior thesis, University of California, April, 1940.
9. "A Study of Viscous Oil and Rotary Mud in Gravel Packing," by J. H. Douma and H. O. Palmer. Senior thesis, University of California, April, 1938.
10. "Extrusion of Gravel-Pack Through Perforated Casing," by H. Lee Flood. *The Petroleum Engineer*, April, 1939, p. 25.
11. "Gravel-Packing Injection Wells for Recycling Gas is Important Phase of Completion," by H. Lee Flood. *The Petroleum Engineer*, June, 1940, p. 53.
12. "Gravel Packing and Its Application to Oil Production," by G. E. Green. *International Oil*, April, 1940, pp. 27-30.
13. "Screening Effect of Gravel on Unconsolidated Sands," by B. Gumpertz. *A.I.M.E. Petroleum Development and Technology*, 1941, pp. 76-85. See also, *Petroleum Technology*, May, 1940. (Technical Publication 1195.)
14. "Gravel Packing, Some Economical and Technical Considerations," by B. Gumpertz. *International Oil*, October, 1940, pp. 44-48.
15. "Economics of Gravel-Packing in the Semi-Depleted Loma Novia Field," by D. L. Harlan. *The Petroleum Engineer*, April, 1942, pp. 83-88.
16. "A Study of Some Factors Affecting the Screening of Unconsolidated Sands by Gravel in Wells," by K. E. Hill. M.S. Thesis, University of California, 1940.
17. "Factors Affecting the Use of Gravel in Oil Wells," by K. E. Hill. *A.P.I. Drilling and Production Practice*, 1941, pp. 134-143. See also, *Oil Weekly*, May 26, 1941, pp. 13-20.
18. "Sand Pack Solves Well Sanding Problem," by C. Johnston. *Oil Weekly*, June 24, 1940, p. 34.
19. "A Study of the Minimum Thickness and Permeabilities of Gravel Envelopes as Used for the Screening of Unconsolidated Sands," by H. E. Nissen. Senior thesis, University of California, November, 1940.
20. "Gravel Packing for Oil Wells, *Oil and Gas Journal*, September 29, 1938, p. 72.
21. "Gravel Packing Now Common Practice," *Petroleum World*, April, 1939, p. 34.
22. "Progress of Gravel Packing in California," *Petroleum World*, June, 1940, p. 47.
23. "Gravel-Wall Wells," by F. T. Quinn. *Journal, American Water Works Association*, November, 1931, pp. 1719-1723. See also, *Canadian Engineer*, June 30, 1931, p. 15.
24. "Effectiveness of Gravel Screens," by B. H. Sage and W. N. Lacey. *A.I.M.E. Petroleum Technology*, May, 1941. Technical Publication No. 1325.
25. "Gravel-Packed Liners Reduce Well Caving and Sand Production," by T. P. Sanders. *Oil and Gas Journal*, October 14, 1937, p. 59.
26. "New Gravel-Packing Method Permits Recovery of Liner," by T. P. Sanders. *Oil and Gas Journal*, June 5, 1941, p. 92.
27. "Improved Method of Washing Gravel-Packed Liners in Wilmington Completions," by T. P. Sanders. *Oil and Gas Journal*, October 30, 1941, p. A-95.
28. "Gravel-Packing Oil Wells," by W. A. Sawdon. *The Petroleum Engineer*, December, 1937, p. 83; and January, 1938, p. 86.
29. "Improvements in Methods of Gravel-Packing Oil Wells," by W. A. Sawdon. *The Petroleum Engineer*, January, 1939, p. 95.
30. "Perforated Liner is Gravel-Packed Before Being Placed in Well," by W. A. Sawdon. *The Petroleum Engineer*, April, 1939, p. 42.
31. "Pre-Packed Liners Broaden Scope of Gravel-Packing Applications," by W. A. Sawdon. *The Petroleum Engineer*, October, 1940, p. 118.
32. "Gravel-Wall Wells," by R. R. Schweitzer. *Journal, American Water Works Association*, June, 1934, pp. 712-724.
33. "Gravel Envelopes versus Standard Wells," by A. Taylor. *Journal, American Water Works Association*, March, 1932, pp. 369-374.
34. "Completion Practices Related to Well Productivity," by W. J. Travers, Jr. *A.I.M.E. Petroleum Technology*, March, 1942. Technical Publication 1465.
35. "Increasing Production of Petroleum by Increasing the Diameter of Wells," by L. C. Uren. *Transactions A.I.M.E.*, Vol. 71 (1925), pp. 1276-1300.
36. "Sand Control in Oil Production," by L. C. Uren. *The Petroleum Engineer*, April, 1934, pp. 20-23.
37. "Experimental Study of Pressure Conditions Within the Oil Reservoir Rock in the Vicinity of a High-Pressure Producing Well," by L. C. Uren and E. J. Bradshaw. *Transactions A.I.M.E., Petroleum Development and Technology*, 1932, pp. 438-466.
38. "Advantages of Large-Diameter Wells in Exploitation of Oil Fields," by L. C. Uren, F. F. Davis and W. L. Jarvis. *A.P.I. Proceedings*, Vol. 9, Part III, 1928, pp. 94-105.
39. "Influence of Well Diameter Upon Pressure Gradient and Rate of Flow of Oil Through Reservoir Rock in Vicinity of a High-Pressure Well," by L. C. Uren, J. Domercq, and J. Mejia. *Transactions A.I.M.E., Petroleum Development and Technology*, 1935, pp. 25-37.
40. "Perforated Casing and Screen Pipe in Oil Wells," by E. W. Wagy. U. S. Bureau of Mines, Tech. Paper 247, 1920.
41. "Effect of Gravel Screening Upon Unconsolidated Sands," by E. M. Wheeler. M.S. Thesis, University of California, April, 1940.
42. "Wells of Gravel-Wall Type," by C. M. Willis. *Oil Weekly*, April 26, 1937.
43. "Gravel-Wall Wells on the Shore of Lake Michigan," by N. F. Yorkman. *Water Works and Sewage*, November, 1932, pp. 384-386.

—— ☆ ☆ ☆ ——

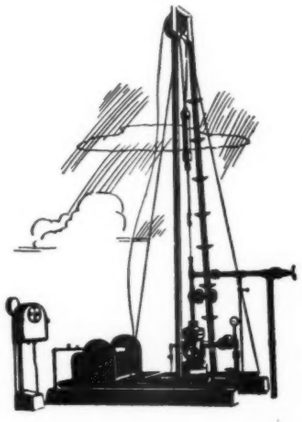
BLUEPRINT FOR PRODUCTION EFFICIENCY

.... today and tomorrow

Faced, as you are today, with restricted allowables, and prospects for more stringent reductions due to extended gasoline and oil rationing, the need for greater economy and efficiency of production is unquestionable. Further complicating the responsibility of bringing oil to the surface is the war-time demand for men, metals, machinery and power. Adding to the complexity of this situation is the inevitable need for greatly increased production necessitated by the gigantic mechanized war machine of the United Nations, which must soon depend entirely upon the United States and South America for its oil.

This seeming paradox is not only solved, but completely obliterated by the Nixon Surface Control Gas-Lift System.

The Nixon Gas-Lift circumvents the war-time demand for men, metals, machinery and power by using many times less of these than older production methods. One man can supervise the operation of many units in a single field. The Nixon Gas-Lift does not require the tons of metal needed for the older type equipment.... Its power is cheap gas pressure frequently supplied by nature itself.



Nixon Surface Control Gas-Lift equipment is available now. Today's restricted allowables make it absolutely necessary that your wells produce at the lowest possible cost. The Nixon Surface Control Gas-Lift System is the only answer to this necessity. Tomorrow's quick demand for greatly increased production can only be met by this same system.

But don't wait for tomorrow. Let our engineers show you how immediate installation of the Nixon Gas-Lift will lower production costs . . . how it will prepare you to meet the zero hour of increased production. Talk to a Nixon Gas-Lift Engineer, for the good of your country and yourself. Write the nearest Wilson Supply store or sales office.

WILSON SUPPLY COMPANY

1412 Maury Street — **Houston, Texas**

SALES OFFICES: **Tulsa, Oklahoma; Dallas, Texas. LOS ANGELES—Western Pressure Control Co., 5700 Santa Fe Ave. TRINIDAD, B. W. I.—Neal Massey Eng. Corp.**

BRANCH STORES: **TEXAS—Gladewater, Barbers Hill, Bay City, Monahans, Alice, Victoria, Corpus Christi. LOUISIANA—Lake Charles, New Iberia, Harvey, Shreveport.**

NIXON *Surface Control* **GAS-LIFT SYSTEM**

Methods of Cleaning Corrosion Coupons

PETROLEUM ENGINEER Exclusive Feature

☆ **Proper cleaning of coupon is extremely important to obtain correct measurement of weight and pitting**

by C. E. Lee and A. C. Alter

Southern California Gas Company

C. E. LEE

graduated from Oregon State College in mechanical engineering—Served with naval and army air corps—Since 1939 has been a member of technical supervisor's staff of Southern California Gas Company—A photograph and biographical sketch of A. C. Alter is unavailable, as he is now in the United States Army.

IT HAS become common practice to use corrosion coupons to predict the rate of corrosion and the useful life of pipe lines. These coupons are placed in the soil at points where the underground reaction is to be determined and are allowed to remain there for some definite period of time, usually one year. When removed for examination the coupons will be covered with a considerable coating of rust and scale, and in order to insure a correct measurement of weight and pit depth at the time of removal all the corrosion products must be taken off without any appreciable removal or addition of metal. It is important, therefore, that the coupons be cleaned properly. The several cleaning methods in common use are herein compared.

Corrosion coupons are, in general, plates of the same material as the pipe line and must be exposed to the same corrosive conditions as the buried metal. The coupons used for determination of corrosion of steel pipe lines usually are mild steel strips sawed from hot-rolled steel bars. The strips are approximately ⅛ in. by 2 in. by 6 in. in size and are sandblasted, drilled for attachment to the pipe line, cleaned, weighed, and numbered for identification. They are commonly employed in pairs, one being a pipe coupon and the other a control coupon. The pipe coupon is electrically connected to the pipe line and is subjected to the combined corrosive action of the soil, of long-line currents, and of any extraneous currents. The control coupon is not electrically connected to the pipe and is subject only to the corrosive action of the soil. Pitting and weight loss due to soil corrosion, however, will vary from year to year with different conditions of rainfall, irrigation, drainage, etc.

Cleaning methods in common use are given in Table I. The cleaning action of a hot aqueous solution of ammonium citrate is purely chemical in nature, but coupons have been cleaned by this method.

Cathodic (electrolytic) methods of cleaning were developed by the U. S. Bureau of Standards.[2] Aqueous solutions of sulphuric acid have been the most common electrolytes[1, 2, 3, 5] employed, but an aqueous solution of sodium carbonate and sodium hydroxide has recently been used.[4] Cleaning by cathodic methods depends upon the mechanical cleaning action of the bubbles of hydrogen (formed under the corrosion products) upon the coupon, which is the cathode in the cleaning electrolyte. When cleaning by this type of method the corrosion coupon is cathodically protected from loss of metal. The apparatus used for cathodic cleaning is shown diagrammatically in Fig. 1.

The results of tests on the effect of current density on coupon weight (parent metal) for both electrolytes are given in Fig. 2. The curves here show that a current density of not less than approximately 0.1 amp. per sq. in. prevents loss of metal from a corrosion coupon in the sulphuric acid electrolyte, but in the alkaline electrolyte (sodium carbonate-sodium hydroxide) a slight but insignificant gain in weight is experienced at all current densities.

The effect of the concentrations of sulphuric acid electrolyte, sodium hydroxide-sodium carbonate electrolyte, and ammonium citrate solution on coupon weight (parent metal) is shown in Fig. 3. The concentration of the sulphuric acid electrolyte has little effect upon the weight loss of metal of the corrosion coupon during the cleaning process, whereas the concentration of the ammonium citrate solution influences greatly the loss of metal from the corrosion coupon. It is evident that an ammonium citrate solution strong enough to remove rust and scale from

TABLE I

Methods of cleaning corrosion coupons

1. Chemical cleaning		
Cleaner:	Ammonium citrate	2 percent aqueous solution
	Operating temperature	212°F.
2. Cathodic cleaning		
A. Cleaner[1, 2, 3]:	Sulphuric acid	2 percent aqueous solution
	pH	0.6
	Current density	0.024 amp. per sq. in.
	Operating temperature	room temperature
B. Cleaner[4]:	Sodium carbonate	3-5 oz. per gal.
	Sodium hydroxide	0.4-0.8 oz. per gal.
	pH	12.6-13.2
	Current density	0.139-0.416 amp. per sq. in.
	Operating temperature	180°F.

Pulsing the *Veins* of the Oil Industry... De La Vergne Diesel Engines

Night and day, over mountains and under rivers, through forests and swamps, crude oil must be kept flowing. De La Vergne Diesels have been the steadfast heart pumping the oil through miles of pipe line arteries ever since 1907.

Today, more than ever before, oil pipe lines require dependable power to keep the flow constant, from field to refinery—to Victory. De La Vergne Diesel Engines are providing this constant power at hundreds of far-flung pumping stations with quiet efficiency.

Based on years of experience in this specialized service, De La Vergne engineers have developed a diesel engine for every oil pipe line job. You can get a dependable De La Vergne Diesel Engine in sizes ranging from 200 bhp to 1,500 bhp.

BALDWIN

De La Vergne

SALES CORP.

BLW THE BALDWIN GROUP

SUBSIDIARY OF THE BALDWIN LOCOMOTIVE WORKS • PHILADELPHIA

BUILDERS OF DEPENDABLE ENGINES SINCE 1880

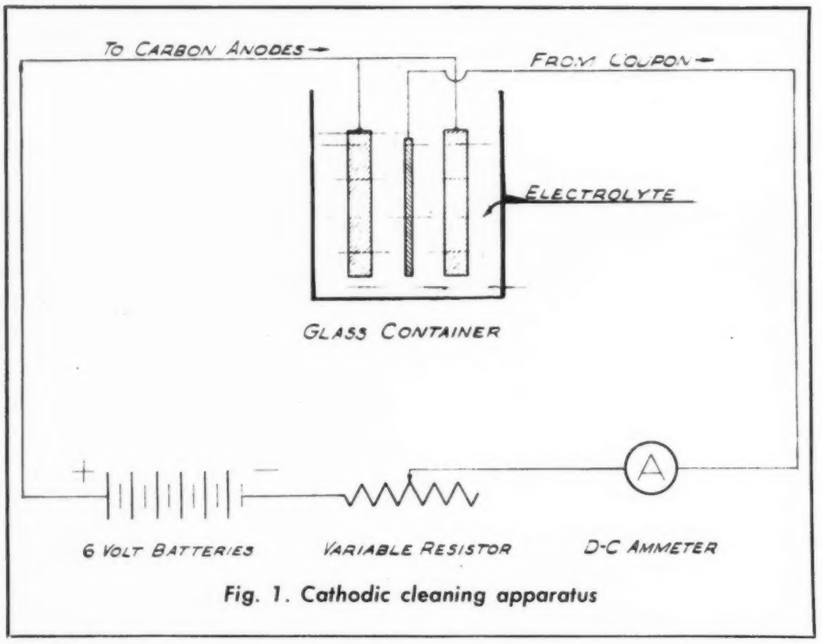


Fig. 1. Cathodic cleaning apparatus

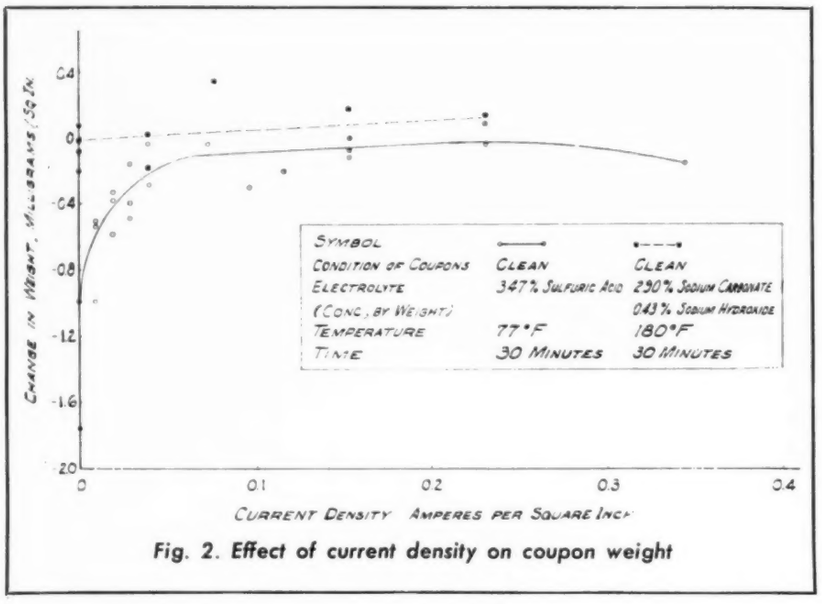


Fig. 2. Effect of current density on coupon weight

the corrosion coupon also dissolves a large amount of metal. The ammonium citrate solution must therefore be used only in a glass container if contamination and changes in concentration of the solution are to be prevented.

The effect of cleaning time on coupon weight (parent metal) is given in Fig. 4, which indicates that an increase in cleaning time has but little effect on coupon weight (parent metal) for cathodically-cleaned coupons using either the sulphuric acid or the sodium carbonate-sodium hydroxide electrolytes. The loss of metal from the corrosion coupons, cleaned chemically with the ammonium citrate solution, increases greatly with an increase in the cleaning time, this increase being roughly proportional to time.

In Fig. 5 is shown the effect of solution temperature on coupon weight (parent metal) for the sodium carbonate-sodium hydroxide electrolyte.

Comparison of Methods

A comparison of the cleaning abilities of the methods discussed above were made by cleaning seven 2-in. by 5-in. coupons that were cut from a section of severely corroded 4-in. steel pipe that had recently been removed from the earth. The results of the cleaning operations are given in Table 2. Four of these coupons were cut from the bottom of the pipe and three from the top. Those taken from the bottom were severely corroded and contained several penetrations. Those from the top of the pipe were heavily corroded with pits of less than 0.050 in. Two of these coupons, one from the bottom very seriously corroded and one from the top heavily corroded, were cleaned by both methods, using the ammonium citrate solution and the sulphuric acid and sodium carbonate-sodium hydroxide electrolytes.

TABLE 2
Cleaning corroded coupons

Cleaning method	Solution concentration, percent by volume	Current density, amp. per sq. in.	Cleaning time, min.	Temperature, °F.	Initial weight, grams	Weight after cleaning, grams	Cleaning loss, grams	Weight after brushing, grams	Brushing loss, grams	Total weight loss, grams	Percent of total weight loss due to cleaning
Ammonium citrate solution	1.96	.....	30	212	142.6787*	140.7442	1.9345	137.2330	3.5112	5.4457	33.5
	1.96	.....	30	212	259.7870†	258.1402	1.6468	257.7230	0.4172	2.0640	79.8
Sulphuric acid electrolyte	1.96	0.0385	30	77	143.4175*	142.3141	1.1034	140.0003	2.3138	3.4172	32.3
	1.96	0.0385	30	77	264.2206†	263.1665	1.0541	261.4245	1.7420	2.7961	37.7
	1.96	0.0385	120	77	176.4333*	173.4404	2.9929	171.7484	1.6920	4.6849	63.9
Sodium carbonate-sodium hodroxide electrolyte	4 oz. per gal. Na_2CO_3 and 0.6 oz. per gal. NaOH	0.0385	30	180	164.4468*	163.5755	0.8713	157.1160	6.4595	7.3308	11.9
	ditto	0.0385	30	180	220.3278†	220.0147	0.3131	218.8690	1.1457	1.4588	21.5

*–Coupon from bottom of pipe—very severely corroded.
†–Coupon from top of pipe—heavily corroded.

"CLEVELANDS"

Forerunners of All Full-Crawler Ditchers . . .

ASSURES MAXIMUM RETURN ON YOUR INVESTMENT

"Uncle Sam" having first call on all production for "the duration," it's mighty important to keep present equipment in top condition.

Right now because of the government need for materials used in the manufacture of ditching machines, "Cleveland" is closely limited to supplying equipment for "Defense Pipe Lines" and for the various branches of the United States Military and Naval Services. This means production for civilian equipment must be held in abeyance.

"Clevelands" built of the finest and best adapted materials procurable have proven their ability to stand up and deliver long maximum performance under the toughest working conditions. Due to the fact, that under war regulations, new machines are not easily available, present equipment is called upon for more than normal service.

Cleveland owners appreciate more than ever the unit-type construction permitting quick, easy field replacements and repairs. This means not only economy in maintenance but a minimum of delays and a big saving of time and labor.

Write today for Parts Catalog and let us help you keep your CLEVELANDS IN TOP CONDITION FOR LONG PLUS SERVICE.

THE CLEVELAND TRENCHER COMPANY

"Pioneer of the Small Trencher"

20100 ST. CLAIR AVENUE **CLEVELAND, OHIO**

"CLEVELANDS" *Save More* — Because they *Do More*

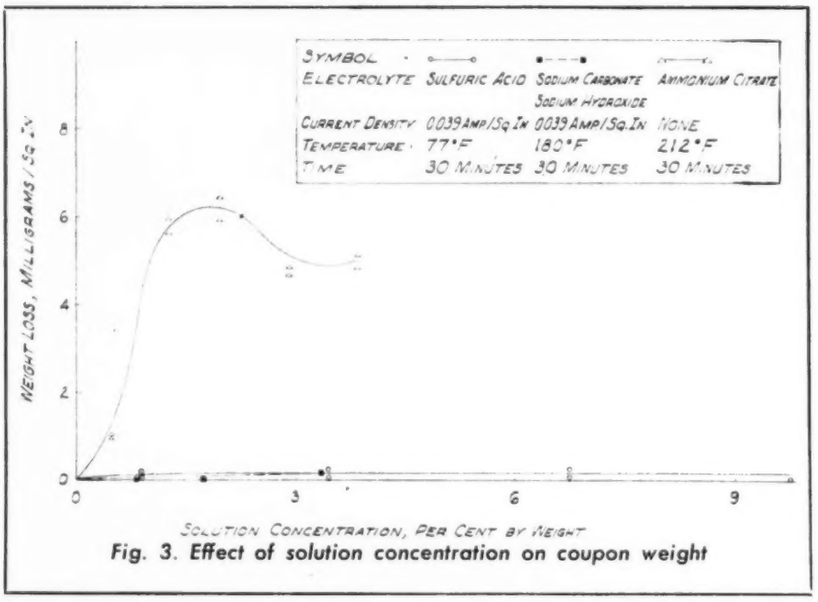


Fig. 3. Effect of solution concentration on coupon weight

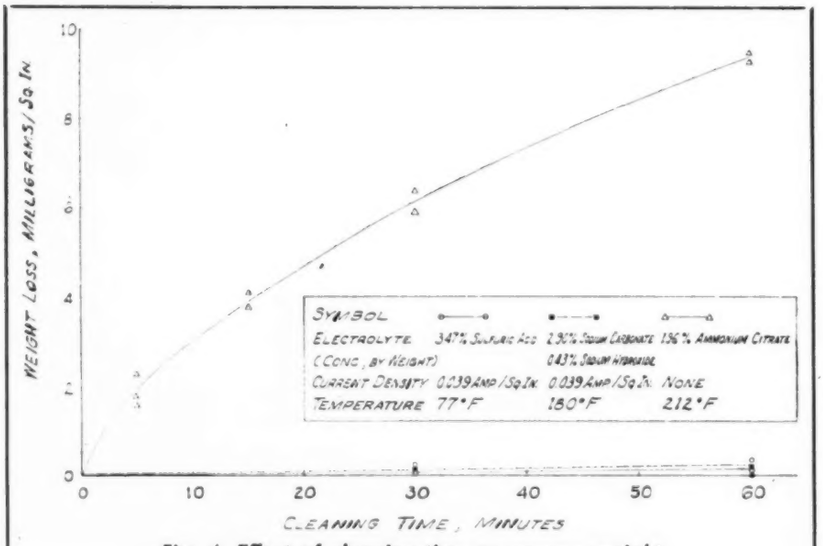


Fig. 4. Effect of cleaning time on coupon weight

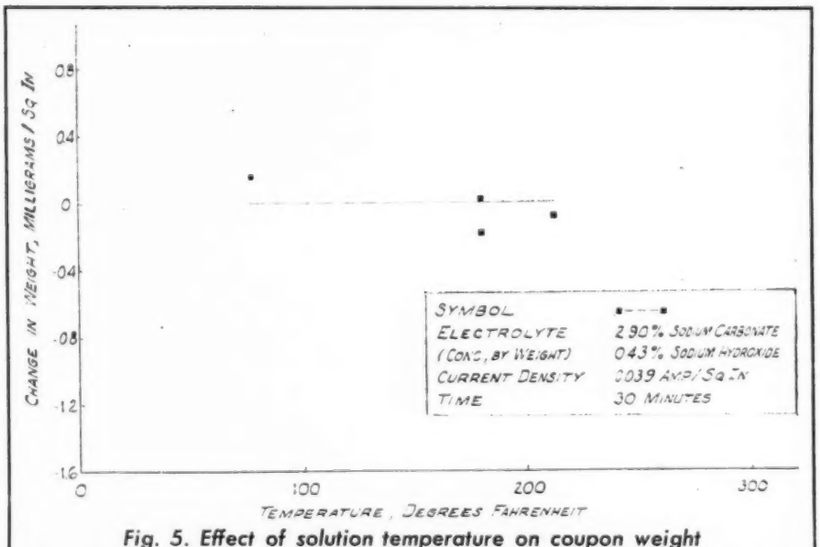


Fig. 5. Effect of solution temperature on coupon weight

From Table 2 it can be seen that the chemical cleaning method using the ammonium citrate solution removed more rust and scale from the corrosion coupons in the same cleaning period, regardless of the extent of the corrosion, than was removed from the coupons cleaned by the cathodic cleaning method using either electrolyte. This chemical cleaning method, however, also produced the greatest loss of parent metal during the cleaning period. (See Fig. 4) Another coupon was cleaned by the cathodic cleaning method, using the sulphuric acid electrolyte, and the cleaning period was increased from 30 to 120 minutes. As indicated by Table 2, this increase in cleaning time resulted in more effective removal of the rust and scale from the corrosion coupon. A further increase in cleaning time would result in the complete cleaning of the rust and scale from the coupon without appreciable increase in the loss of weight of the metal. This also would be true of the cathodic cleaning of corrosion coupons using the sodium carbonate-sodium hydroxide electrolyte.

The cathodic cleaning of corrosion control coupons, using either the sulphuric acid or the sodium carbonate-sodium hydroxide electrolyte, apparently has definite advantages over the chemical cleaning method using an ammonium citrate solution. The cathodic cleaning method is easily controlled, produces little change in weight of the metal of the coupon, and effectively removes the corrosion products.

To obtain full advantage of the effective cleaning of the coupons it is recommended that immediately preceding their installation, corrosion coupons be shotblasted instead of sandblasted because it has been found that approximately 0.001 gram per sq. in. of sand adheres to a sandblasted coupon. There is a loss of weight of the coupon due to atmospheric corrosion during storage and in California this amounts to approximately 0.002 gram per sq. in. per month.

Bibliography

1. "Corrosion Coupons and Pipe Life Predictions," by W. R. Schneider, P.C.G.A. Proc., Vol. 32, p. 154, 1941; *Gas Age*, Vol. 88, No. 7, p. 21.
2. "Electrolysis in Concrete," by E. B. Rosa, Burton McCollum, and O. S. Peters, National Bureau of Standards Technologic Paper No. 18, p. 89, August 1, 1919.
3. "Electrolytic Corrosion of Iron in Soils," by Burton McCollum and K. Logan, National Bureau of Standards Bulletin No. 25, p. 7, June 12, 1931.
4. "The Corronizing Process of Metal Coating," *Metal Finishing*, by R. Rimbach, July, 1941.
5. "Progress in Metals," by W. L. Nelson, *Oil & Gas. Jl.*, Vol. 40, No. 44, March, 1942.

☆ ☆ ☆

Economics of Design and Operation for Pressure Maintenance and Condensate Recovery*

☆ **Extensive investigations provide data for plant design and determine relative value of pilot plant and full-scale production data**

by E. O. Bennett, C. R. Williams, and G. O. Kimmell

DURING the last three years much has been written about pressure maintenance and retrograde condensation. Scientific study of phase relationships of the various hydrocarbons making up gases and liquids has contributed valuable data for the use of engineers in plant design.

The economic design of a retrograde condensate or high-pressure absorption system for the recovery of usable constituents from the hydrocarbon composition from high-pressure reservoirs may be classified a follows: (1) Design and operation of surface equipment; (2) Subsurface flow and pressure control.

Subsurface pools may be in the gas phase (vapor) or liquid phase or a combination of the two. There are few reservoirs containing vapor only. Most of them have gas caps overlying oil bodies at the flank edges of the structure. The relative sizes of the gas and oil zones and the actual subsurface volume of each have much to do with the determination of the type of production operation to be used.

Pressure maintenance is applicable to practically all recovery methods whether the hydrocarbon composition is originally in the gas or liquid phase or in both phases. It may be defined as the return of gas to producing zones to prevent reduction of formation pressure for continued production. Pressure decline in the case of an oil producing zone decreases the available energy for the production of oil and increases the amount of energy required to produce a unit quantity because of the effect of the loss of dissolved gases on viscosity and surface tension of the oil.

In the case of a gas (vapor) zone, the loss of pressure causes the reservoir pressure to fall below the dew point; and condensation causes liquids to form, a large percentage of which will wet the sand grains and become irrecoverable.

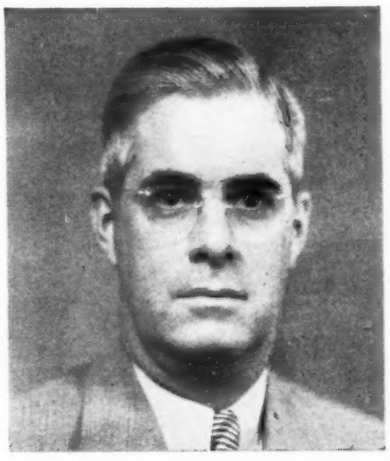
The first practical application of pressure maintenance was that by I. L. Dunn in Ohio in 1903. The art has been commonly miscalled repressuring.

The phenomena of retrograde condensation were discussed by Keunen[1] in 1895. Its effect on high-pressure gas operations was observed in 1925 in Canada and in 1928 in Texas. The effects were, however, not called retrograde condensation or recovery at this time.

The retrograde phenomena have been given much study by engineers, and many recovery plants involving such principles and those of high-pressure absorption have recently been completed. There are now in operation along the Gulf Coast of Texas and Louisiana 23 plants[2] processing 1,081,500,000 cu. ft. of gas per day. This gas is yielding approximately 25,000 bbl. of high-gravity product. Additional plants are under construction, and the production is expected to be increased 75 percent within the next six months.

It can readily be seen that condensate recovery and pressure maintenance in connection with oil production are becoming important features of the oil industry. These recovery methods as now practiced are the very highest

(Continued on Page 102)



E. O. BENNETT

chief production engineer for the Continental Oil Company, this year was presented the Hanlon Award by the Natural Gasoline Association of America for outstanding service to the natural gasoline industry—He graduated from Stanford University in 1917 and that same year became associated with the Standard Oil Company of California—Was technical advisor for the U. S. National Advisory Committee for Aeronautics from 1918 to 1919—Returned to Standard in 1919—Was petroleum technologist for the U. S. Bureau of Mines, 1924-26—Chief petroleum engineer for Marland Oil Company, 1926-28—Since 1928 has been with Continental.

C. R. WILLIAMS

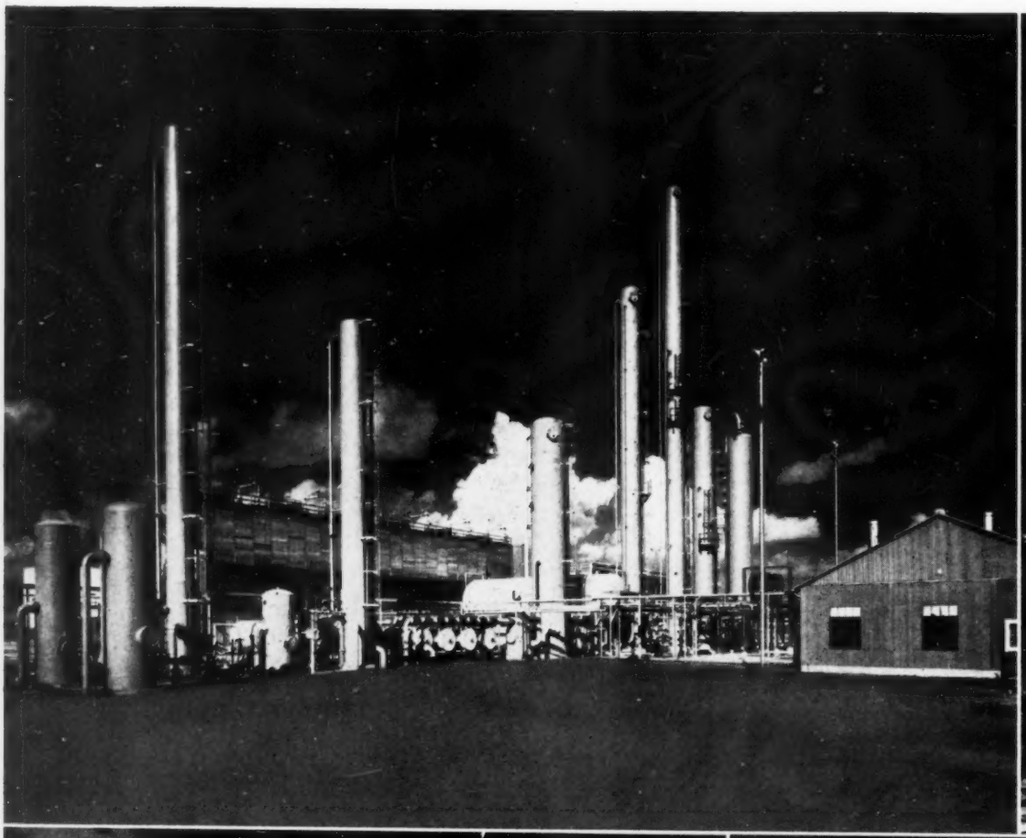
is general manager of the Oil and Gas Division of The Chicago Corporation, Corpus Christi, Texas—He accepted that position April 1, 1942, previously having been assistant superintendent of the Natural Gasoline and Gas Division of the Continental Oil Company, Ponca City, Oklahoma—He graduated from the University of Oklahoma in 1929 with a degree in chemical engineering—Immediately joined the staff of Continental at Ponca City, later being transferred to the company's plant at Baltimore, Maryland—Returned to Ponca City in 1936 where he remained until his recent change.

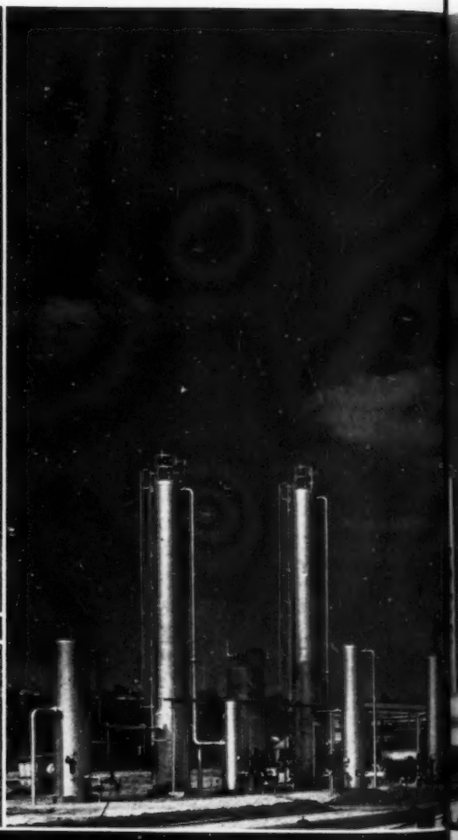
*This paper was presented at the New Orleans meeting of the American Institute of Chemical Engineers, December, 1940.

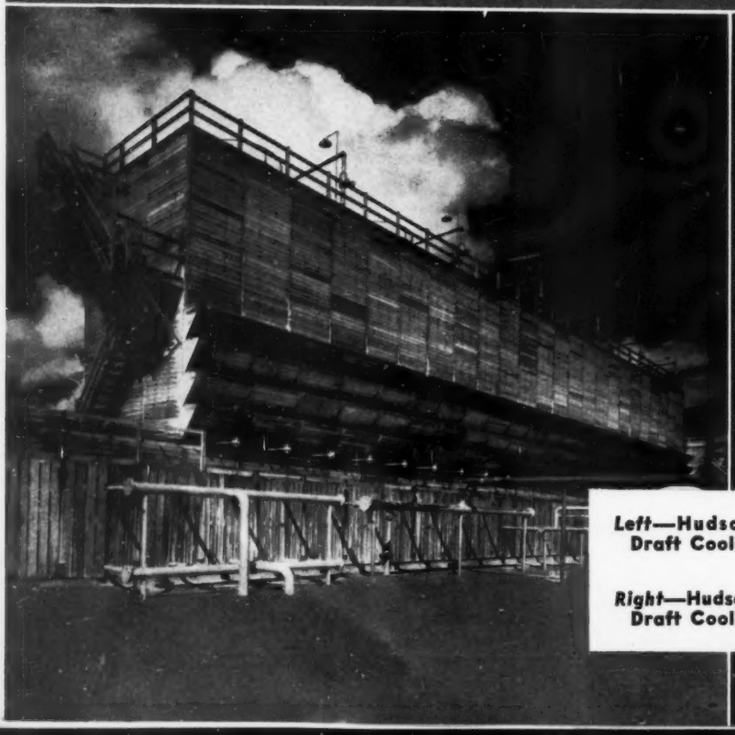
[1] "On the Condensation of Mixtures of Ethane and Nitrous Oxide," *Philosophical Magazine and Journal of Science*, Volume XI, Fifth Series, pp. 173-194, July-December, 1895.

[2] Editor's Note: The number of plants has increased since the paper was written.

HUDSON-BUILT PLANTS PRODUCING "Fuels"



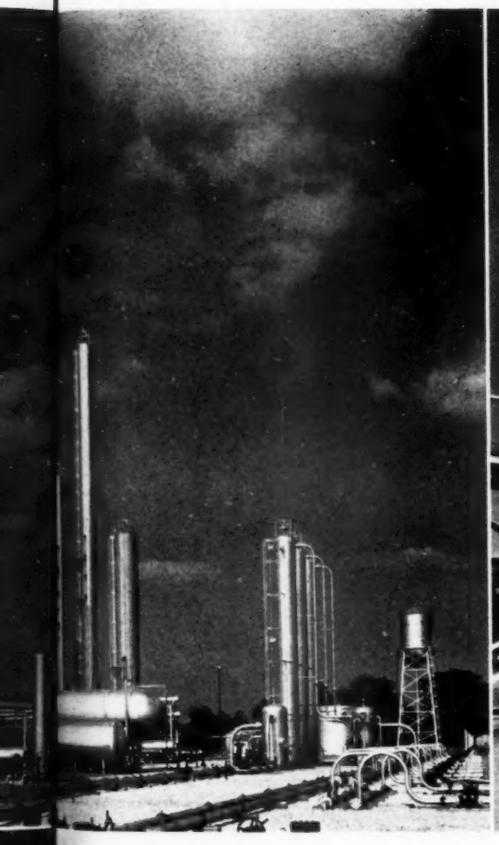


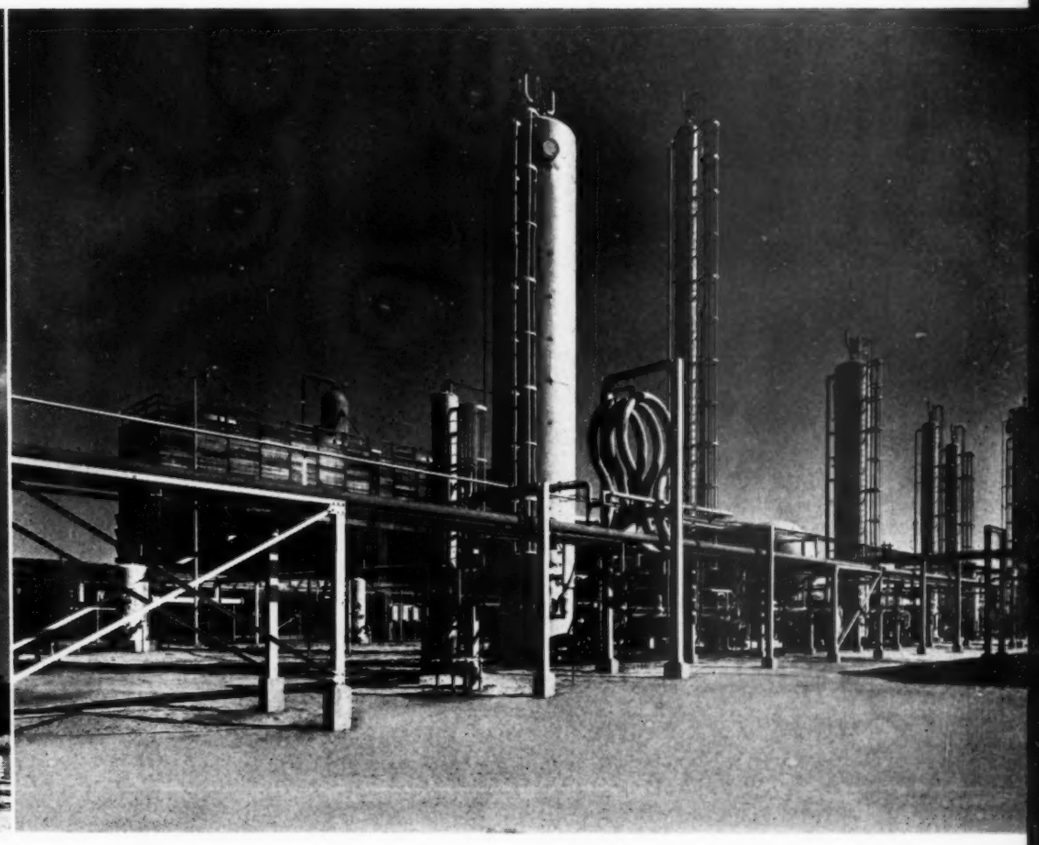


Left—Hudson Induced Draft Cooling Tower.

Right—Hudson Natural Draft Cooling Tower.

s for Freedom"





In refineries, distillate fields and oil fields in Texas, Oklahoma, Illinois and Louisiana, Hudson plants or equipment are contributing to the tremendous and constantly increasing flow of fuels for war, including high purity propane, butanes, pentanes, and closely fractionated high octane aviation blending stocks.

To the refining, producing and gas industries we offer the services of an integrated engineering and construction organization qualified by experience to complete, in minimum time, projects of any size—either independently or in collaboration with our client's engineering departments.

HUDSON COOLING TOWERS

With the mind of the refining industry concentrated on increasing the output of aviation gasoline, synthetic rubber bases, alcohol, toluene and other products essential to war—Hudson is ready with:

1. *Experienced Personnel* to promptly offer Cooling Tower recommendations to best meet the particular cooling problem.
2. *Best Possible Delivery* of all materials, usually within 60 days, for large towers.
3. *Fast Field Erection* by thoroughly experienced crews. Towers are prefabricated in our Houston mill, thus minimizing field erection time and making optimum use of skilled labor.

HUDSON ENGINEERING CORPORATION

Engineers and Constructors

FAIRVIEW STATION • HOUSTON, TEXAS

(Continued from Page 99)

form of conservation to be found in the industry. The residual gas returned has an inestimable value for its heat content when burned as fuel, for reforming to acetylene and butadiene, for the manufacture of synthetic rubber, for explosives, and for numerous other chemical and industrial uses.

The purpose of this paper is to discuss some recently completed investigations conducted on some of the highest-pressure condensate-type wells for obtaining data suitable for the design of a recovery and pressure-maintenance plant.

Another purpose of the tests was to obtain an accurate correlation of the relative value of pilot plant data against full-scale production data. Full-scale test equipment for high-pressure work is very expensive and quite difficult to operate. The results of tests with the equipment described in this article definitely indicate that suitable small-scale equipment properly designed and operated will give satisfactory data and can be operated at low cost with maximum safety.

Fig 1 shows the general arrangement of the full-scale test equipment. Fig. 2 shows the pilot equipment. The use of high-pressure vessels in full-scale equipment often requires strength limitations beyond those required for normal operation and necessitates excess capital expenditures, as such vessels have but little value for other purposes.

The data used in this discussion were obtained from tests on a high-pressure well south of Jennings, Louisiana. The well is 10,000 ft. deep and had an initial formation pressure of approximately 7500 lb. per sq. in.

Normal pressures for wells 10,000 ft. in depth are about 4400 lb. per sq. in., which is the equivalent of a pressure equal to that exerted by a column of salt water of the same depth. Abnormal pressures of this magnitude indicate possible present, or past, communication with deep-seated source beds through faulting. It is the writers' belief that producing zones below 16,000 or 17,000 ft. may be prevalent in areas where pressures far exceeding those normally expected are encountered. (These deductions are made from an analysis of physical phenomena and are not based upon geology.)

G. O. KIMMELL

is research engineer for Black, Sivalls and Bryson, Inc., Oklahoma City, Oklahoma—Received a B.S. degree in petroleum engineering from the University of Oklahoma in 1936, and an M.S. degree in petroleum production engineering from the same school in 1937—Immediately went to work for Black, Sivalls and Bryson as research and development engineer—Has conducted well tests and research work in many states, as well as in Canada—Is a member of Tau Beta Pi, honorary engineering fraternity, and an associate member of Sigma Xi, a fraternity for the development of research.

Field Tests

The summary of a test conducted by Continental Oil Company and Black, Sivalls, and Bryson, Inc., on an extremely high-pressure well is presented in the following sections. The well was of the "condensate" type, drilled by Continental Oil Company in the Gulf Coast region.

Physical characteristics of the reservoir fluid were observed at pressures from 500 lb. to 4240 lb. over a range of temperatures from 80 to 200°F.

The test cycle and the sampling device, used to divert a part of the well stream into the small-scale equipment, were especially developed for this particular test.

Solid lines on the accompanying graphs are continuous over the range of experimental control. Extrapolations are dotted but may be considered fairly accurate in cases where they terminate in known limiting values.

Base conditions for gas measurement are 14.4 lb. per sq. in. and 60°F. All liquid volume measurements are corrected to 60°F., and liquid gravities are compared to water at 60°F.

Apparatus

In Fig. 2 is shown a flow diagram of the small-scale test equipment. The test unit was piped with $\frac{5}{16}$-in. O.D. seamless steel tubing, terminated in special heat-treated steel adapters. The separator was a seamless steel forging 6 in. O.D. by 1 in. thick. The entire unit was set up and tested to 9000 lb. before installation at the well.

The separator, supercompressibility bomb, and solubility bomb were all arranged in an agitated water bath for close control of temperature. The bath was heated by an atmospheric steam coil and cooled by added ice.

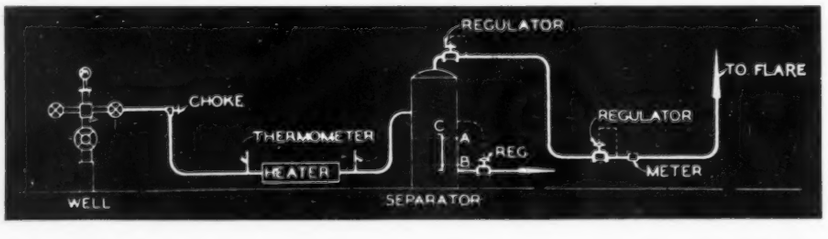
The rate of accumulation of equilibrium liquid in the separator was determined by a set of three lances equally spaced in the liquid section of the separator under protecting baffles. The entrance orifice of the inside end of the lance pointed directly downward so as to be completely submerged at contact with liquid. The lance was conducted through the water jacket to a steam exchanger on the outside and terminated in a special very fine needle valve.

During the runs, a small constant flow of gas was established through each of the lances in turn, a safe time before the expected liquid-level contact. The heat exchanger prevented freezing in the small needle valve. At contact of the liquid level with the lance orifice, atomization through the needle valve produced smoke. Immediately after contact, the valve was closed. The volume of gas passing through all three lances represented less than 0.1 percent of the gas passed through the separator for a run. This method of determining the rate of fill-up in the separator proved to be accurate to 0.2 percent and is considered suitable for all practicable purposes.

The well-stream sample was passed through a coil, needle valve, second coil, and second needle valve, in series, before entering the separator. The temperature of a steam-heated water bath containing the two coils was adjusted so that, after throttling from flowing wellhead pressure to separator pressure, the sample stream was taken overhead through a steam-heated boiling water bath and throttled directly into a critical flow orifice prover. The critical flow orifice plates used were carefully machined from stainless steel and accurately calibrated.

All instruments used on the equipment were carefully calibrated. The included volumes between the liquid level

Fig. 1



SPECIFY THE RIGHT SIZE CONTROL VALVE!

USE-FISHER ALIGNMENT CAPACITY CHARTS

1 TO OBTAIN BEST CONTROL

The *RIGHT SIZE* Automatic Controller assures better performance and longer trouble-free operation than the valve that is incorrectly sized. There is always a correct size for every set of operating conditions.

2 TO EFFECT GREATER ECONOMY

The *RIGHT SIZE* Automatic Controller effects substantial savings in initial cost and in maintenance expense. Charts avoid "over-sizing" of control valves — a costly procedure in both performance and investment.

3 TO CONSERVE VITAL METALS

The *RIGHT SIZE* Automatic Controller requires the minimum amount of vital metal. Correctly sizing control valves is a definite aid to the nation's metal conservation program.

FISHER Alignment Capacity Charts — developed from actual test data — provide a simple, accurate and dependable method of sizing FISHER automatic controllers to meet specific operating conditions. Bulletin AL contains charts for all fluids, covering both single and double port valves and various types of inner valves. Also includes complete instructions for using each chart. Write for your copy today.

FISHER GOVERNOR COMPANY, 600 FISHER BLDG. MARSHALLTOWN, IOWA

lances and the bomb volumes were also carefully calibrated.

Sampling

In order for a small-scale investigation to be successfully conducted on a well, an accurate sample must be obtained from the well stream. A small-scale investigation could be conducted on the total well stream with the well flowing at a very low rate, but at such low rates the quality of the well stream varies in excess of allowable errors. It has been discovered that an accurate sample of the flow can be removed with a thin-edged cylindrical nozzle if the well is flowing at a sufficiently high rate to insure a constant upward movement of all parts of the stream past the point of sampling and if proper rates through the nozzle are maintained.

Ordinarily, a sample nozzle and supporting tube are lubricated into the wellhead, but on this high-pressure test, a special sampling section of heavy pipe was built onto the wing of the tree. The sample nozzle and tube were placed in the section before opening up the well. Forty internal diameters of straight pipe were allowed upstream and 20 diameters downstream from the sampling nozzle. The well was back-pressured at a point downstream from the nozzle so that tests at full flowing wellhead pressure could be made.

The exact behavior of a thin-edged cylindrical nozzle in its sampling operation cannot be positively determined, but in Fig. 3 is a logical explanation.

"Velocity Ratio" will be used as a term to indicate the ratio of linear velocity inside the nozzle to the linear velocity in the sampling section around the nozzle. The reduction of pressure and temperature up the tubing (or casing) of most condensate-type wells causes condensation in the stream before it reaches the wellhead. Under sufficient flow conditions for accurate sampling, this condensate is in the form of fine droplets. (At low rates of flow, the droplets coalesce and cause the well to head.)

In Fig. 3, the sample nozzle is shown in place in the sampling section. In "a," the velocity ratio is greater than one. Under this condition, the nozzle would remove more vapor from the sampling section than would normally pass the cross-sectional area of the nozzle tip if it were not in position. The flow pattern at the nozzle tip would be a cone with its apex upward. A

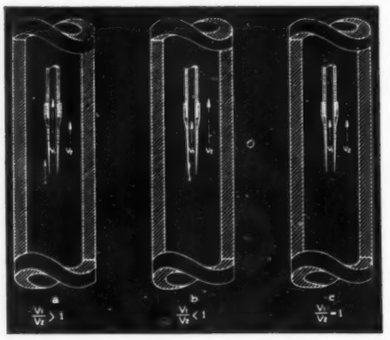


Fig. 3

liquid droplet rising in the space between the cone and a projection of the cylindrical nozzle, because of its inertia, might break through the surface of the cone and pass up beside the nozzle. This "bypassing" of droplets would reduce the amount of liquid that should be removed with its associated vapor and give an indication of too low a liquid-vapor ratio in the separator. In "b," the velocity ratio is less than one; and the apex of the flow pattern cone would point downward. By the same reasoning, this condition should result in the indication of too high a liquid-vapor ratio in the separator. At "c," where the velocity ratio is unity, the presence of the cone disappears, and there is no tendency for bypassing in either direction.

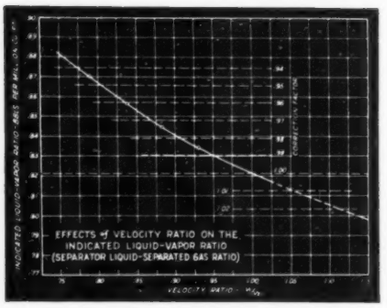


Fig. 4

In Fig. 4, we find that the above-mentioned effects of velocity ratio on the indicated liquid-vapor ratio are true. The curve in Fig. 4 was developed by purposely varying the sampling rate and observing its effects on the liquid-vapor ratio in the separator. At the point where the curve crosses the unity velocity ratio line, the nozzle was removing a representative sample, and proof of this lies in the close check to full-scale tests that were run.

It is impossible to hold exactly unity velocity ratio throughout the test, so a correction graph is developed from the curve in Fig. 4. The scale marked "correction factor" represents the magnitude of the correction to be applied to the indicated liquid-vapor ratio.

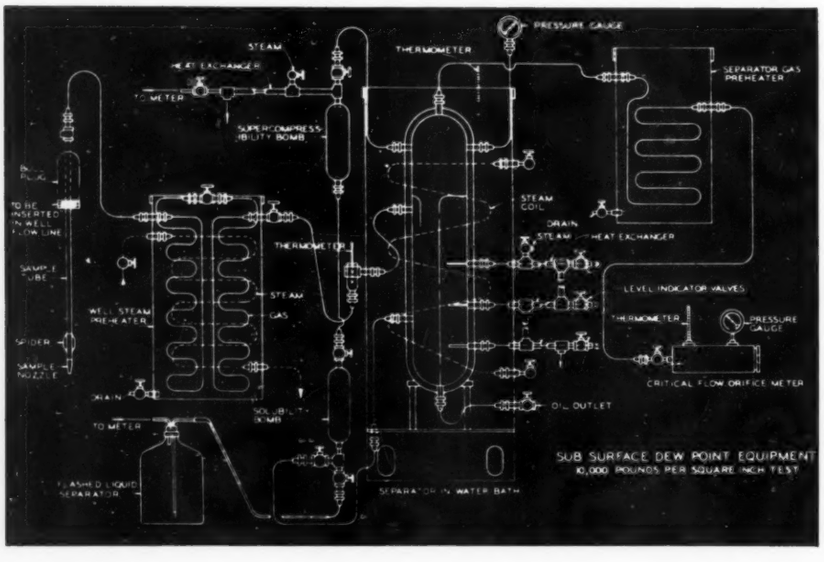
The velocity ratio is calculated for each run on a weight basis and a correction obtained from Fig. 4.

Separated Liquid Characteristics

The term "separator liquid" is analogous to "equilibrium liquid" and refers to the volume of condensate remaining as liquid at separation conditions of pressure and temperature. The term "separated gas" has reference to the associated gas or "equilibrium vapor," which is at the same pressure and temperature as the separator liquid.

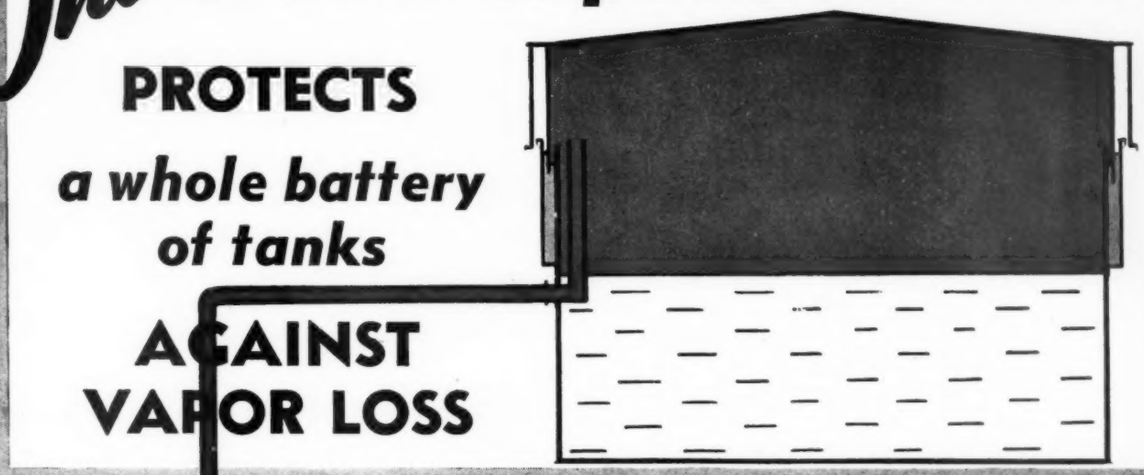
In Fig. 5 is shown the separator liquid-separated gas ratio in bbl. per 1,000,000 cu. ft., plotted against pressure for 80, 110, 140, 170, and 200°F. Several bottom-hole pressure and temperature measurements were made, and the average values were 6500 lb. and

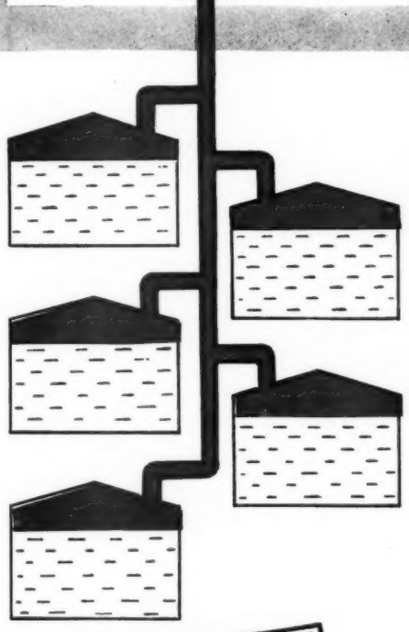
Fig. 2



One Graver Expansion Roof

PROTECTS *a whole battery of tanks* AGAINST VAPOR LOSS





Graver has made vapor conservation practical, efficient, and economical. Evaporation losses are eliminated — completely. Not just for the contents of one tank, but for many. For one Graver Expansion Roof, installed on a tank of suitable size, will handle the breathing of the entire battery, the number of tanks which can be manifolded to it depending upon the capacity of the Expansion Roofed tank.

The principle is simple enough. The Expansion Roof rises and falls as the vapors expand or contract and, liquid sealed all around, it holds the vapors instead of expelling them. There is *no vapor loss.*

But manifolding is but one of the advantages offered by the Graver Expansion Roof. Just consider these, also.

- **Low Installation Cost.** Only one roof to buy to protect the contents of a whole battery of cone roof tanks.
- **Complete Protection.** Vapor losses eliminated. Octane rating maintained. Filling losses reduced to a minimum.
- **Low Maintenance.** Requires minimum of attention. Will last longer than ordinary cone roof tank. No breathing in of moisture-laden air.
- **Self Draining Roof.** Conical shape prevents accumulation of snow or water.
- **Easy Adjustment.** All equalizing equipment inside protected from the weather. Can be adjusted from outside without taking tank out of service.

Graver Expansion Roofs are saving thousands of dollars worth of gasoline and protecting its quality as well, at pipeline and marine terminals of major oil companies all over the country.

And they can do the same for you. Why not get the facts? Write Graver — today.

WATER SOFTENERS
•
FILTRATION SYSTEMS
•
CLARIFIERS
•
SEWAGE DISPOSAL EQUIPMENT
•
STEEL STORAGE TANKS
•
VAPOR CONSERVATION SYSTEMS
•
WELDED CONSTRUCTION
•
STRESS RELIEVING
•
X-RAYING
•
FABRICATED STEEL AND NON-CORROSIVE PLATE

GRAVER

GRAVER TANK & MFG. CO., INC.

NEW YORK
CATASAUQUA, PA.

4809-30 Tod Ave.
EAST CHICAGO, IND.
CABLE ADDRESS — GRATANK

CHICAGO
TULSA

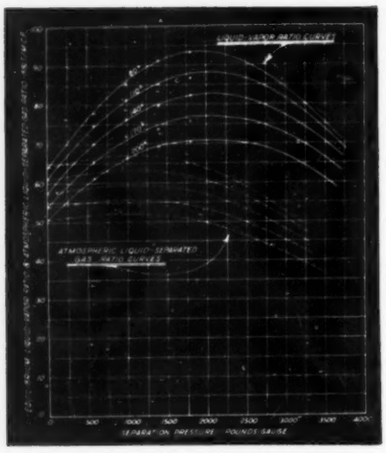


Fig. 5

208°F. Extrapolation of these curves indicates that at 6500 lb. and 208°F. all hydrocarbons are present in the reservoir as dew-point vapors. The reservoir pressure could not be lowered without causing condensation of liquid in the reservoir pore space.

The return of residue gas to the producing zone is the only known method of preventing subsurface condensation. Because of the mass temperature of the earth at the reservoir, no practical effect can be economically carried out toward temperature change or control.

A large percentage of any subsurface condensate formed is used in the film wetting of sand grains and becomes irrecoverable at the surface.

An explanation of the crossing of the 80°F. isobar across the higher temperature isobars is presented in Fig. 6. Fig. 6 is shown for the purpose of illustration only and is not intended to be used as engineering data. Consider a point "P" in the low liquid-vapor ratio region on the 5 percent isobar close to reservoir pressure. Point "P" could progress at constant pressure in the direction of increasing temperature into a region of increased liquid concentration.

From the envelope curve Fig. 6 constructed from data obtained from the high-pressure well test, it can be seen that any drop in pressure from the reservoir dew point will cause an increase of liquid recovery until such pressure declines to 2400 lb., the optimum pressure value. It can also be seen that a reduction of temperature will further increase the liquid content recoverable. These factors then suggest a combination control for recovery that includes a reduction of both temperature and pressure.

The horsepower, and consequently the cost of machinery, required to compress gas from the range of optimum recovery to a pressure high enough for return of the gas to the producing zone can be readily calculated. Thus the compression cost for each percent of increased recovery can be determined.

The cost of refrigeration or cooling for each percent of increased recovery due to temperature reduction may also be evaluated from the same curves.

With known unit costs for both pressure and temperature effect, the most economical plant may be designed. From such data it can be readily seen that simple water cooling would increase the recovery efficiency of a plant working on the retrograde recovery cycle.

Cooling through an extreme range calls for elaborate refrigeration; and greatly reduced temperatures require a high degree of dehydration of gas to prevent the formation of hydrates,

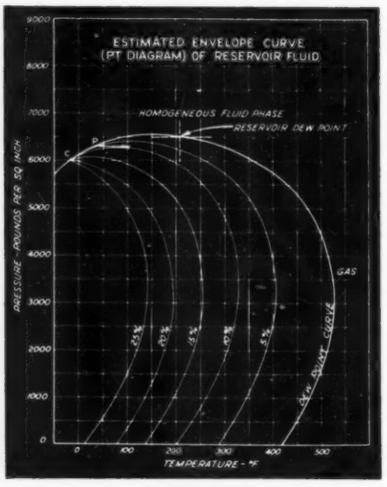


Fig. 6

which rapidly plug the system and interrupt operations.

An analysis of the chart, with known costs of compression, refrigeration, and dehydration, suggests the consideration of not attempting to recover the ultimate quantity of liquid by retrograde operations alone but partly by retrograde and partly by absorption of the condensable fractions leaving the retrograde separator and passing through a high-pressure absorber.

After determining the liquid-vapor ratio, a sample of the equilibrium liquid was taken into a pre-equalized solubility bomb. After filling completely, the bomb was isolated and its contents flashed directly to atmospheric pressure.

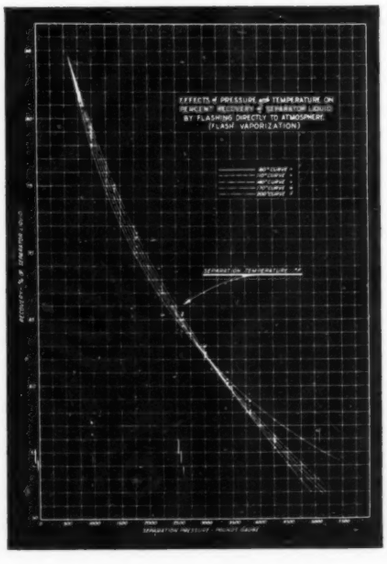
This type of gas liberation from a liquid yields the most vapor and least liquid. It is called flash evaporation and may be explained by a liquid system from which the gas is *not* removed from contact with the liquid, as the reduction in pressure allows the gas to come out of solution. Except for the rather small volume of gas remaining in the bomb after the last drop of liquid was withdrawn, the vaporization was true flash.

It is tedious to make a true flash vaporization determination of solubility and shrinkage in the same operation, so the interference of a partial differential vaporization in the bomb was tolerated. The magnitude of this interference, determined on a number of occasions, has been found too slight to warrant separating the solubility and shrinkage determinations.

The recovery curves shown in Fig. 7 indicate the percent recovery of separator liquid by flash vaporization. Percent recovery as plotted is 100 times the ratio of atmospheric liquid to separator liquid. The percent shrinkage (100 minus percent recovery) represents the partial volume of separator liquid occupied by the solution gas. At a separation pressure of 0 lb. gauge, the recovery would be 100 percent (a definite limiting value).

Fig. 8-A shows the effects of separation pressure and temperature on the atmospheric liquid-separated gas ratio. The values in those curves represent the bbl. of liquid at atmospheric pressure separated from 1,000,000 standard cu. ft. of separated gas. The atmospheric liquid-separated gas ratio values were determined by multiplying the liquid vapor ratio (Fig. 5) by the recovery (Fig. 7) for the various identical separation conditions. A full-scale check run was carefully conducted over a 24-

Fig. 7



BROWN TRIPLE AID for "ALL OUT" PRODUCTION

IN "All Out" production of war materiel both employees and management are confronted, daily, with new and difficult problems of manufacturing processes involving temperatures, pressures, flows and liquid levels.

Brown *Triple Aid* is a service ideally suited to help solve such problems and enable your organization meet the Quality and Quantity production so essential to Victory.

Brown and Minneapolis-Honeywell engineers are qualified to recommend the control system best suited to your requirements — either electric — pneumatic or combined electric and pneumatic. Intimate knowledge of process control is based upon years of practical organization in the field — backed by a large organization with competent research facilities.

Brown Indicators, Recorders and Controllers are designed for precision measurement and control of processes under severe industrial working conditions. They will handle efficiently the control of a single process or the completely coordinated control of continuous processes.

Brown Periodic Instrument Service is maintained for your benefit and convenience. With offices strategically located in all principal cities, emergency repairs, regular inspection or counsel are quickly and readily available.

Call a Brown representative to explain in detail the advantages of Brown *Triple Aid* and the benefits you can obtain by using this service.

ENGINEERING

INSTRUMENTATION

NATION WIDE SERVICE

For Temperatures . . . . . Pressures . . . . . Flows . . . . . Liquid Levels

BROWN INSTRUMENTS

ELECTRIC • AIR OPERATED

THE BROWN INSTRUMENT COMPANY, 4475 WAYNE AVENUE, PHILADELPHIA, PENNSYLVANIA

DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR CO.

MINNEAPOLIS, MINNESOTA, AND 119 PETER STREET, TORONTO, CANADA

Wadsworth Road, Perivale, Middlesex, England — Nybrokajen 7, Stockholm, Sweden

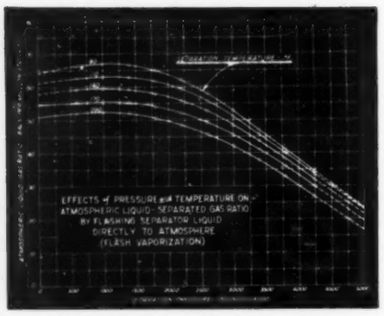


Fig. 8-A

hour period to determine the accuracy of the test unit. The full-scale separator operated at a pressure of 675 lb. gauge and an average temperature of 81°F. Separated gas measurements and stock tank gaugings indicated an atmospheric liquid-separated gas ratio of 66.0 bbl. per 1,000,000 cu. ft. This point is shown as a star on Fig. 8-A for comparison. Full-scale and test operations checked each other to 0.6 percent.

Fig. 9 shows the atmospheric liquid gravities for various separation conditions. The gravities are in degrees A.P.I. at 60°/60°.

The solubilities indicated in Fig. 10 represent the volume of gas that was in solution under separator pressure per bbl. of liquid recovered at atmospheric pressure. The solubility curves in Fig. 10 should not be confused with solubility curves as normally run on a single liquid. Every point on the solubility curves indicates the volume of gas obtained from a different condensate sample by flash vaporization. The nature of the separator liquid varies with separation conditions of pressure and temperature. At separation conditions of 0 lb. gauge, the solubility is 0 (a definite limiting value).

The specific gravity of the separator liquid was calculated from 15 liquid analyses taken over the complete range of pressures and temperatures. In Table 1 are shown the vapor volumes used to convert the observed fractional analyses data to liquid volume percent.

Fig. 8-B

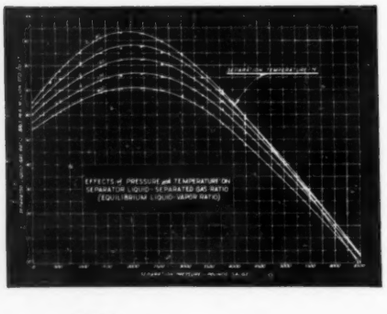


TABLE 1

Component	Vapor volume (Std. cu. ft. per gal.)
Methane	62.6
Ethane	47.7
Propane	38.4
Butanes	32.4
Pentanes	28.1
Hexanes Plus	15.4

The volume and specific gravity of the hexanes plus residue were measured on all the liquid analyses. Molecular weight determinations were run on six representative residues and a correlation made between specific gravity and molecular weight. The correlation is shown in Table 2.

TABLE 2

Equilibrium liquid sample—pressure and temperature	Specific gravity	Molecular weight
991- 80	0.7807	154.0
991-140	0.7860	161.4
991-200	0.7913	168.7
1800- 80	0.7829	157.1
1800-140	0.7868	162.5
1800-200	0.7908	168.0
2600- 80	0.7871	162.9
2600-140	0.7700	166.9
2600-200	0.7927	170.7
3400- 80	0.7923	170.1
3400-140	0.7943	172.9
3400-200	0.7962	175.5
4240- 80	0.7981	178.2
4240-140	0.7995	180.1
4240-200	0.8007	181.8

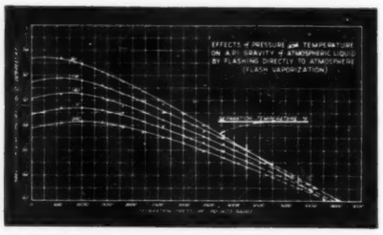


Fig. 9

Corrections for compressibility and expansibility were applied to the liquid volume analyses to correct them to the conditions of pressure and temperature in the separator. In Fig 11 is shown the most logical picture for the effects of separation pressure and temperature on the separator liquid specific gravity. This specific gravity was used to calculate the weight of liquid separated in the test unit as part of the velocity ratio calculations.

Separated Gas Characteristics

The several equilibrium vapor analyses were combined in the proper ratio with their respective equilibrium liquid analyses, and the average composite obtained is presented in Table 3.

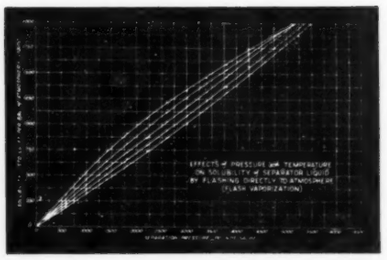


Fig. 10

TABLE 3

Component	Mol percent in reservoir fluid
Methane	87.118
Ethane	4.319
Propane	1.956
*Iso*butane	0.752
Normal Butane	0.541
Pentanes	0.792
Hexanes Plus	4.522

The composite analyses indicate a specific gravity of 0.842 and a 26-70 natural gasoline content of 3.73 gal. per M. cu. ft. for the totally vaporized well stream.

In. Fig. 12, the supercompressibility or "misbehavior" of the separated gas is shown plotted against pressure for the five temperatures. Supercompressibility is a measure of the deviation from the perfect gas laws and can be defined as:

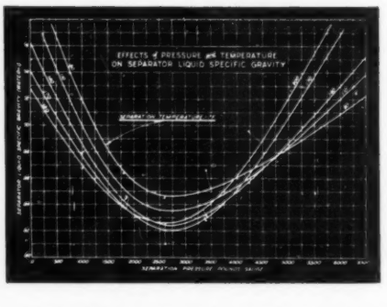
$$K = \frac{P_1 V_1 T_2}{P_2 V_2 T_1}$$

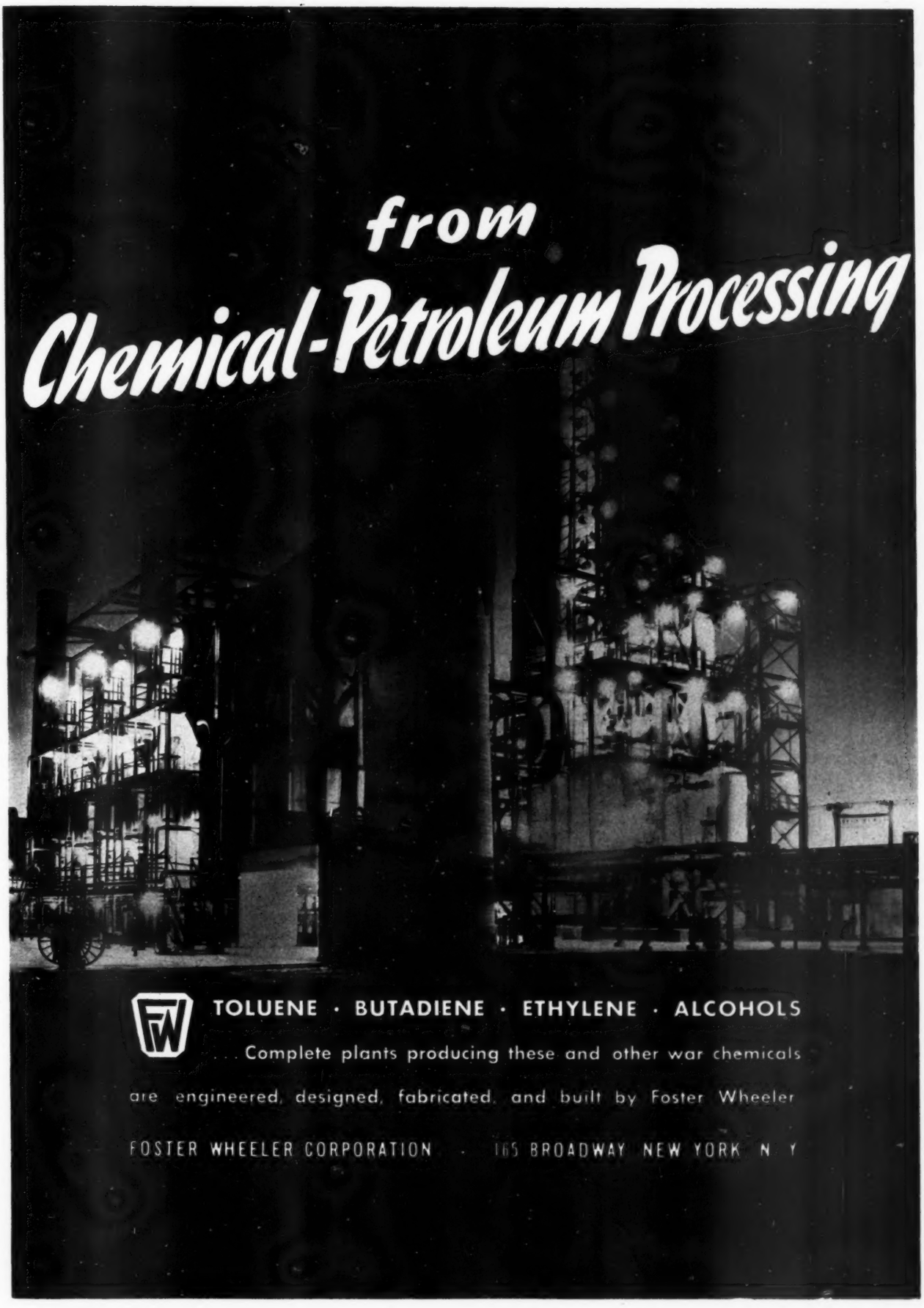
in which:

P_1 = elevated pressure, lb. abs.,
V_1 = volume at the elevated pressure, in cu. ft.,
T_2 = temperature at base pressure, °R.,
K = supercompressibility factor,
P_2 = base pressure, lb. abs.,
V_2 = volume at base pressure, and
T_1 = temperature at the elevated pressure.

The factors in Fig. 12 show the deviation of equilibrium vapor at the indicated pressure and temperature, separated at the same pressure and temperature. In other words, the supercom-

Fig. 11




from
Chemical-Petroleum Processing
TOLUENE · BUTADIENE · ETHYLENE · ALCOHOLS
. . . Complete plants producing these and other war chemicals
are engineered, designed, fabricated, and built by Foster Wheeler
FOSTER WHEELER CORPORATION · 165 BROADWAY NEW YORK N Y

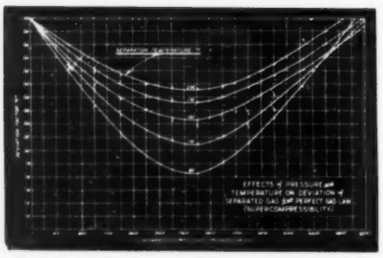


Fig. 12

pressibilities are not for one given vapor but for different vapors, the composition of which is a function of the P_1 T_1 conditions.

The standard pipe-line orifice meter supercompressibility factor can be obtained from the "K" values in Fig. 12 by:

$$F_{pv} = \sqrt{\frac{1}{K}}$$

The "K" values used in this way for full-scale gas measurement give absolutely accurate results only when the meter is in the gas line from the separator and carrying full separator pressure and temperature. The supercompressibility curves, however, check surprisingly close with factors determined on a single vapor of composition approximating the average compositions of the equilibrium vapors for the entire test.

Supercompressibility data plotted from tests as shown in Fig. 12 check very closely with pseudo reduced temperature and pressure determinations for methane as developed by Dr. G. G. Brown.

When an accurate pressure-indicating device is not available, the effect of deviation on the gas column in a well must be understood before the formation pressure may be calibrated from the known density at some pressure and the shut-in pressure at the wellhead.

A pressure bomb using the principle of a Brinnell testing machine was developed and satisfactorily used for the measurement of extreme pressures. With a metal of known hardness, the pressure may be determined by the size of the indenture of the impressor point.

Accurate fractional analyses on vapor samples at pressures above the retrograde condensation point are extremely difficult. Liquid analyses at these pressures are much more easily made, so it was decided to run several vapors at nominal pressures, determine an accurate composite, and calculate the composition of the vapors by subtracting the liquid from the composite (shown in Table 3) in the proper ratio. Gas gravities calculated from the vapor compositions thus obtained are shown in Fig. 13. The weight of gas separated was determined by using these gravities. The gravity of 0.842 can be considered as a fairly accurate limiting value for the 200°F. isobar.

The 26-70 natural gasoline content of the vapor compositions obtained as explained above is shown in Fig. 14. Here the figure of 3.73 can be considered as a fairly accurate limiting value for the 200°F. isobar.

Reservoir Pressure Decline

Fig. 15 was developed from the data to show the effects of producing the reservoir without returning gas (cycling) to prevent a decline in pressure. The graph was developed on the basis of separation aboveground at 1000 lb. and 80°F. A recovery efficiency curve m-o-n is indicated for a separation cycle without processing the separated gas for its natural gasoline content. An efficient curve e-s-r is indicated for the same cycle with the recovery of the natural gasoline content.

Practically, it would be impossible to reduce the reservoir pressure to 0 lb.,

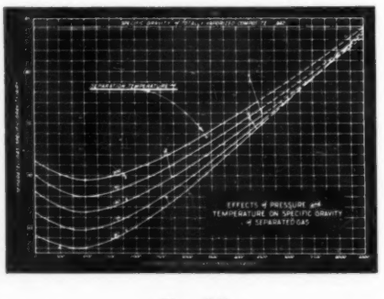


Fig. 13

but the complete reduction is shown for sake of illustration. It is also assumed that a natural gasoline recovery plant would operate at 100 percent efficiency.

Assuming complete dissipation of reservoir pressure, 46.3 percent of the total equivalent 26-70 content of the reservoir could be recovered without processing the separated gas. An additional 14.5 percent, or a total of 60.8 percent, could be recovered if all the equivalent 26-70 content of the well stream were recovered aboveground. It cannot be determined what the recovery efficiency would be were cycling employed to maintain the reservoir pressure, but 85 percent might be expected.

Assuming the conservative figure of 85 percent, cycling would mean the recovery of an additional 25 percent of the total recoverable content of reservoir fluid. Then, too, if cycling were employed, the reservoir would contain a large part (approximately 94 percent) of the gas it contained at the start of the project (disregarding fuel requirements for operation that would come from the separated gas).

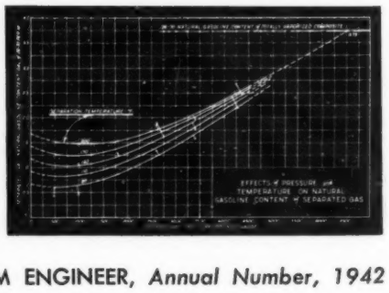
Vaporization Equilibrium Constants

The mol composition of both equilibrium liquid and equilibrium vapor was determined. The ratio of the mol concentration of a constituent in the vapor to the concentration of the same constituent in the liquid is its "K" value. The "K" values for 80 and 200°F. are shown in Figs. 16 and 17. The curves are not recommended for use in vaporization problems. Even though the probable errors in the curves could be tolerated in the solution of some problems, it must be remembered that they were developed for a specific reservoir gaseous fluid. (The curves are presented mostly as a matter of interest.)

The natural mixtures of hydrocarbons occurring in the so-called retrograde fields are so complex that present knowledge of their behavior is far less than is needed to answer the requirements of this new branch of the petroleum industry. Even the fundamental answer on the constituents composing these mixtures cannot be completely obtained; however, as several of the constituents can be determined and because of the interrelation between members of the hydrocarbon families, it is possible to derive generalizations from experiments on a given system that, if applied within proper limits, will assist greatly in the solution of practical problems.

The curves and data that have been presented herein supply some of the general characteristics of this particular field's hydrocarbon system upon which the basis of facts for design can be predicated. The boundaries of this system are the physical walls wherein all hydrocarbon constituents are considered a part of the system. The walls are measured in terms of pressure, volume, time, and the thermodynamic quality. The extensive properties, which are directly proportional to the amount of material involved, and the intensive properties such as pressure and temper-

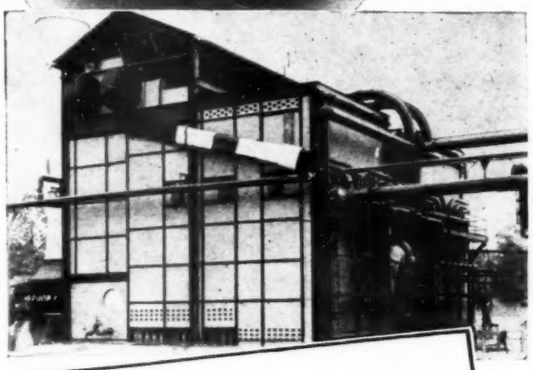
Fig. 14



VOGT STEAM GENERATORS

selected for

LAKE CHARLES REFINERY, CONTINENTAL OIL COMPANY

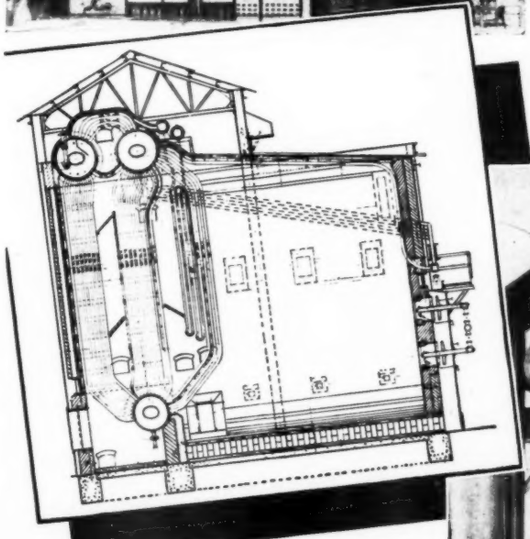


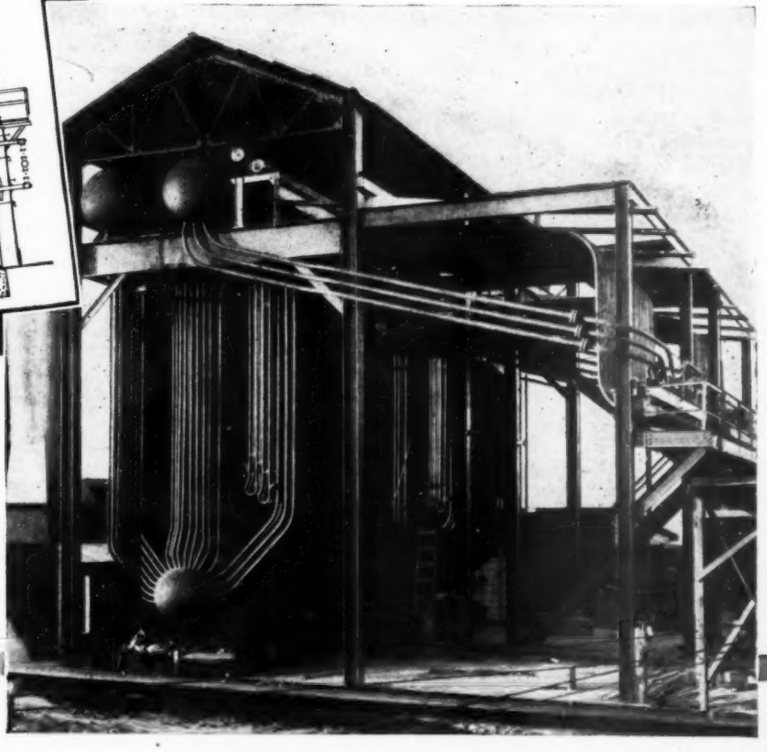
Each of the two units comprising this installation is designed to deliver 95,000 pounds of steam per hour with 165 degrees of superheat, using feed water at 212 degrees F.

Steam and water drums are fusion welded and designed for 400 pounds working pressure.

Furnace walls and floors are air cooled and the furnace roofs water cooled. Burners installed in each furnace are arranged to burn Natural Gas or Refinery Gas Fuel.

These units are provided with a roof only and are operated out in the open like oil stills.





Bent Tube and Sectional Header Type Boilers for any fuel!

Vogt WATER TUBE BOILERS

HENRY VOGT MACHINE CO., Inc., LOUISVILLE, KY.

Branch Offices: *New York • Philadelphia • Cleveland • Chicago • Cincinnati • St. Louis • Dallas*

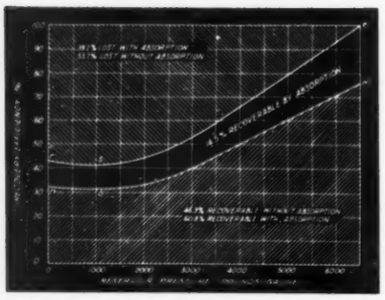


Fig. 15

ature, which are independent of the quality of material involved, are both of vital concern to the design engineer.

From the data on equilibrium constants shown in Figs. 16 and 17, the design engineer is able to determine the "K" factors that should be used in determining the component composition of the liquid and vapor phases that would result from any particular set of temperature and pressure conditions. From chart No. 8-B can be obtained the optimum pressure from the standpoint of pressure versus maximum yield at a series of temperatures and further, an estimate can be made of the desirable constituents that cannot be recovered by the temperature-pressure relationship under consideration. As absorption processes have not been proved successful at pressures much in excess of 1800 lb. per sq. in., the design engineer must determine the quantity of material that can be recovered by further reduction of pressure from perhaps 2500 lb. to 1800 lb. and determine whether the additional recovery obtained will justify the expenditure required in absorption equipment and additional compressors for returning the gas to sufficient pressure for reinjection.

Generally it is found that such expenditures cannot be justified, as the material is actually not lost but is returned to the producing formations in cycling operations and also because under proration it is doubtful whether any additional quantity of usable material can be produced than could be produced under a fixed allowable for a given field. Often it is decided to forestall the installation of the more efficient recovery equipment until more details are known from actual plant operations.

When the optimum temperatures for recovery and pressure are determined, the question of how to obtain the temperature desired is important. For temperatures down to about 85°F., water cooling is generally considered most economical and satisfactory. For lower temperatures, refrigeration equipment with dehydration facilities to prevent formation of hydrates is used. It is in this phase of the design that satisfactory data are most lacking because the thermodynamics of the hydrocarbons are quite lacking in this range.

In order that a basis for design of cooling equipment may be available, actual measurements should be made during the operation of the test equipment and the data thus obtained used for design in preference to the scattered theoretical data. From the heat data and cost of obtaining such temperatures, the engineer can determine the advisability of low-temperature operation when applied to the volumes anticipated in the plant under discussion.

With the flow sheet prepared giving the temperatures and pressures desired in the process, the purchase and sizing of equipment almost parallel those for more conventional plant design when particular care is given to proper materials with regard to pressure and temperature.

An important feature of production operations in connection with condensate recovery from a single-phase reservoir is the proper location of producing and gas-injection wells on the structure. With suitable spacing, it has been found that there is but little mixing of the returned dry gas with the wet reservoir gas. The dry gas displaces the wet gas in a uniform body, and the mixture at the contact zone is slight, for no agitation occurs. Over a period of many years, complete admixture will occur. This time is well beyond the economic life of the project.

The movement of gas under high pressure in a porous media, such as a producing zone, is linearly proportional to the pressure differential causing the movement between the points considered. It is also a well-known fact that the flow of an electric current through a conductor is a corresponding function of the potential difference between the points considered. These similar relationships suggest the use of an electrolytic model map of a producing zone to assist in following the volume occupied by injected dry gas in a single-phase producing zone where condensate is being recovered.

The model is prepared by pouring a zinc ammonium chloride solution with 2 percent by weight of agar over a scale map of the producing zone. The producing wells are represented by cells filled with zinc ammonium chloride and the input or injection wells by cells of copper ammonium chloride. Zinc and copper ammonium chlorides are very suitable for this type of work, as the transference numbers of their ions are nearly alike and the copper gives a well-defined blue color to the electrolytic mass as the current moves from input to producing wells.

The amount of current that corresponds to the volume of gas injected in an input well is calculated, and the current is controlled by proper resistances and instruments. A rectified alternating current is used in this work.

Results of the volume occupied by dry gas determined by the electrolytic method check very closely with volumes calculated by Muskat's formula and also very closely with actual field conditions. The electrolytic method is very convenient to use and provides an excellent means of studying producing conditions in condensate recovery projects.

The flow path of injected gas and the effects of additional injection on

Fig. 16

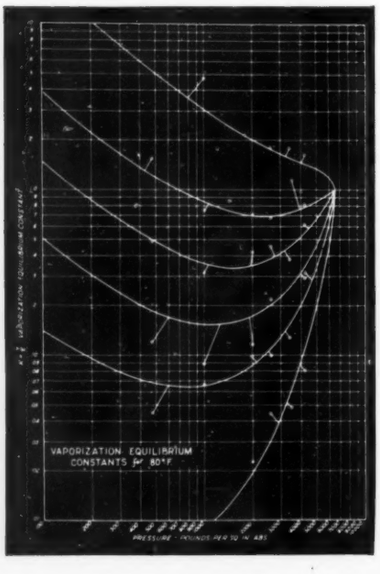
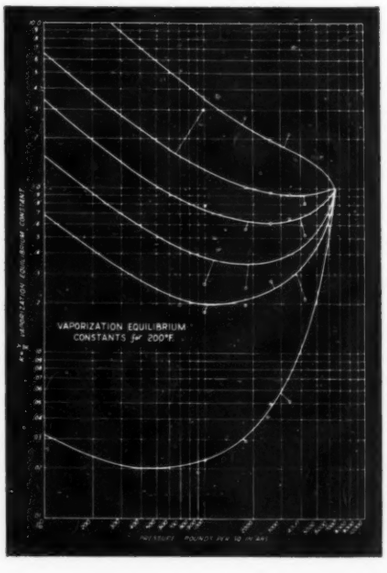
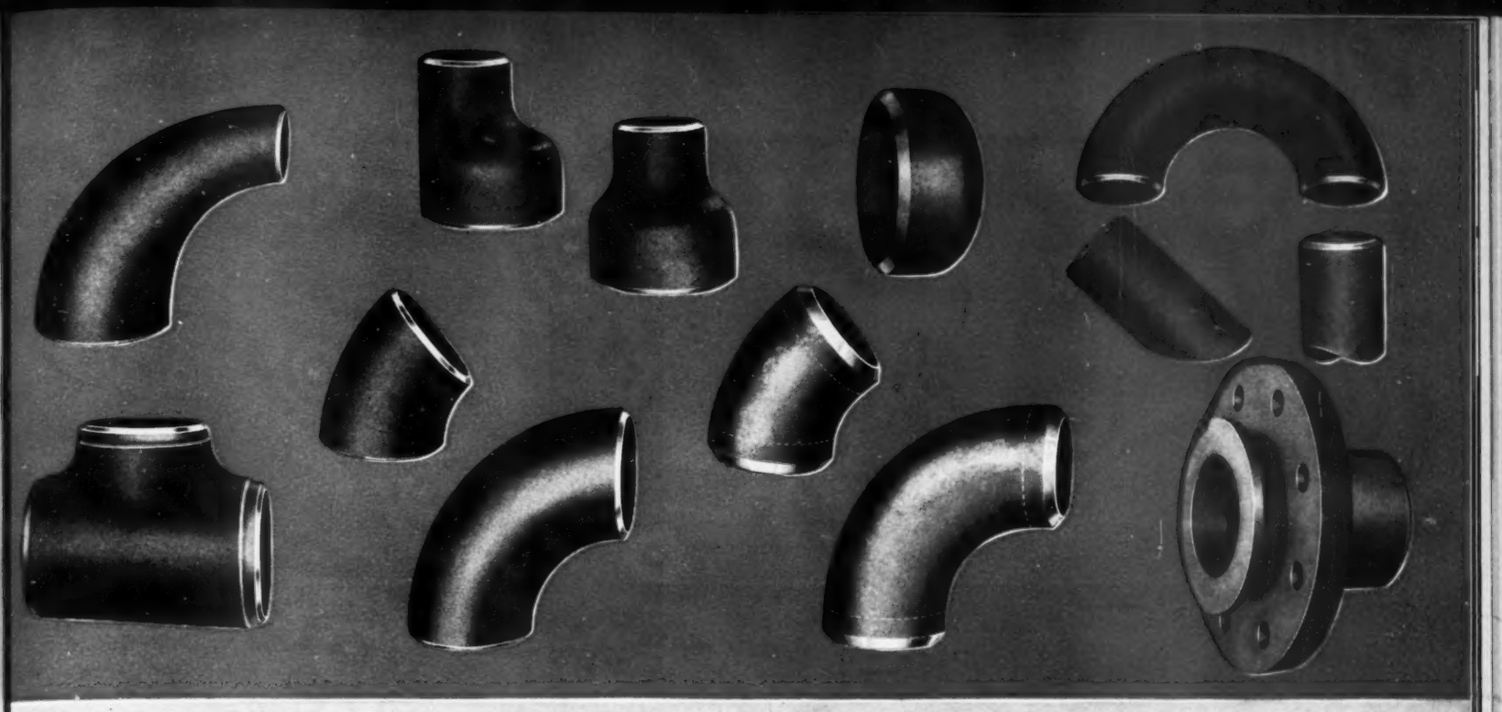


Fig. 17





MIDWEST

THE COMPLETE LINE OF Welding Fittings

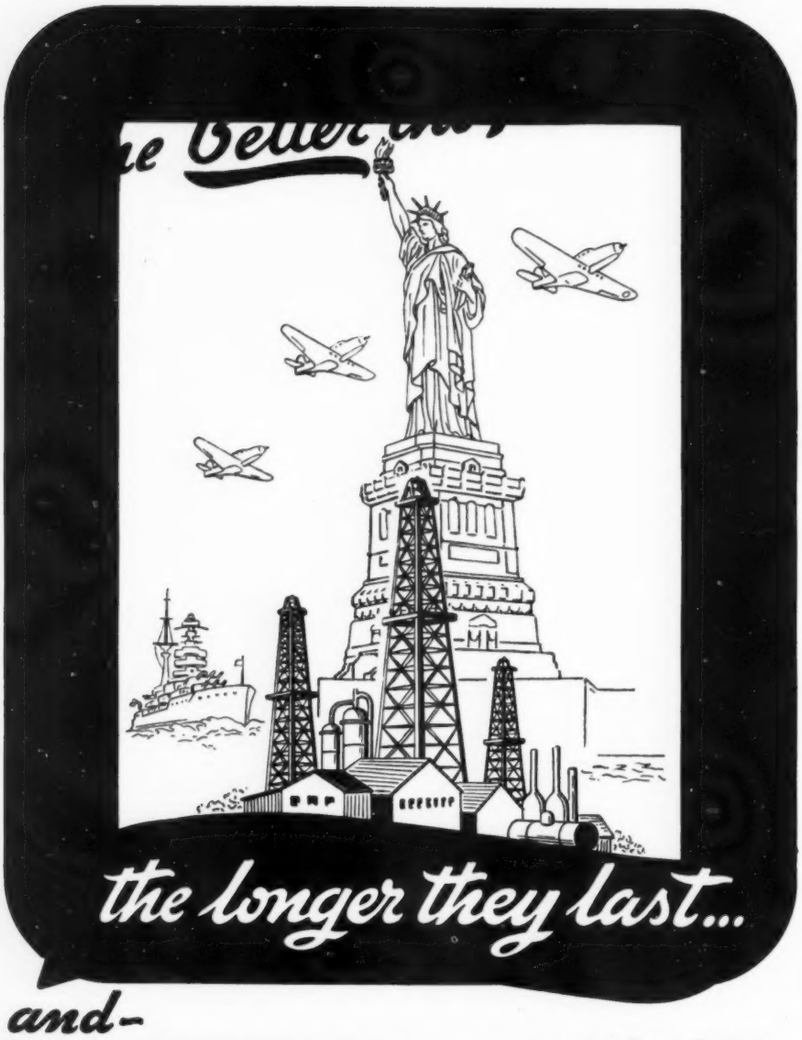
Many users of welded piping are finding it advantageous to standardize upon Midwest Welding Fittings. Important among the reasons for this preference is the fact that only one source of supply is necessary to meet all their needs. . . . Midwest has the most complete line of welding fittings.

Midwest was the first manufacturer to recognize the need for many of the fittings illustrated here. Reducing Elbows, Saddles, Sleeves, "Long Tangent" Elbows and Shaped Nipples are among the fittings developed by Midwest and first offered to the trade by Midwest.

The design and method of manufacture of Midwest Welding Fittings offer the user definite advantages . . . such as exceptional dimensional accuracy. (See Bulletin WF-41 for details.)

MIDWEST PIPING & SUPPLY CO., Inc.

Main Office: 1450 So. Second St., St. Louis, Mo.
Plants: St. Louis, Passaic (N. J.) and Los Angeles
Sales Offices: Chicago—949 Marquette Bldg. • Houston—229 Shell Bldg.
Los Angeles—520 Anderson St. • New York—(Eastern Division) 30 Church St.
San Francisco—535 Call Bldg. • Tulsa—533 Mayo Bldg.



and—
THE LONGER THEY LAST *the better*

The HIGHER STANDARD

It's always been wise to buy the best tools available . . . now it's *vital!* Every day added to the useful life of a piece of oilfield equipment means time and material saved to insure our liberty. Those who, even in normal times, have known that Spang Cable Tools offer a longer period of efficiency, are more grateful than ever now for these "Higher Standard" Tools.

SPANG & COMPANY, BUTLER, PA.

SPANG NAME IN CABLE TOOLS

(Continued from Page 112)

producing wells is readily indicated by the color change in the electrolytic model. By proper observance of the model results, full-scale field operations may be greatly aided.

Construction

The construction of any high-pressure equipment requires that adequate factors of safety be used in all designs for static, shock, and creep stresses due to temperature changes. Temperature ranges over as much as 300°F. may occur in some sections of plant equipment from cold to working conditions.

Ample flexibility in header anchors and expansion joints must be left to permit motion due to temperature change. At the same time, anchors must be suitable to prevent undue vibration caused by pressure surges from compressor discharges. Pressure surges may be extreme when but few compressor cylinders are used and may cause physical destruction of equipment. Pulsation dampeners for breaking up pressure waves in high-pressure gas systems have eliminated such troubles.

Great care must be used in welding heavy pipe sections to eliminate locked-up stresses. Several light beads have proved more satisfactory than a few heavy ones.

Ample reinforcing must be used at all joints where creep stresses due to temperature change may enter.

High-pressure piping and fittings should at all times be exposed for inspection and maintenance. Hair-line cracks back of welds near compressor cylinders are the principal types of failures observed.

Iron ring gasketed flanged unions are recommended for all high-pressure work. No screwed fittings on any gas lines should be permitted.

Adequate relief equipment should be provided to protect all equipment against excessive pressure and liquid carry-over. Frangible disk safety heads are preferred to pop valves, as the latter often freeze in service.

Lubricated plug cocks are more desirable than valves for high-pressure gas work.

Suitable engine stopping devices for failure of water or lubricating oil should be installed. Emergency engine stops for use in the event of trouble should be installed at several points around a plant.

All operating personnel working in or around high-pressure gas operations should be adequately trained in operating procedure around high-pressure plant operations and know how to act in an emergency. A thorough knowledge of first-aid service is an essential part of an operator's training.

☆ ☆ ☆

Determining Productivity Index of Pumping Well by Copper Tubing Method

☆ **Procedure described is simple, rapid, and inexpensive**

THE most familiar and practicable method of determining the productivity index of a pumping well involves running a depth-pressure recorder instrument to record the midpoint perforations pressure at one or more producing rates and the midpoint perforations pressure at equilibrium static conditions.

Usually the method involves a rather lengthy procedure, expensive in both time required and type of equipment used. Outlined briefly, a productivity run requires: (1) shutting the well down to run the recorder, (2) starting the well for the pressure at the desired production rate, (3) producing at the desired rate until equilibrium conditions are reached, (4) shutting the well in for a static equilibrium pressure, and (5) removing the recorder.

The procedure is not only inconvenient, necessitating the loss of several days production in down-time, but also involves the use of expensive equipment. For this reason, determination of productivity indices of pumping wells is often neglected. Many times this results in underestimating producing capacity and consequently lower producible allotments.

So far as is known the procedure for determining the productivity index of a pumping well as discussed in this article has not been tried in the field. As the method appears to be fundamentally sound, however, it is being presented for whatever economic value it may possess.—*Editor's Note.*

The method here outlined presents a simple, inexpensive method of measuring bottom-hole pressures of pumping wells and a rapid means of determining productivity indices. By measuring the rate of rise of fluid in the well rather than the rate of fluid production at the surface, the down-time is minimized.

Productivity Index Defined

Productivity index is defined as the amount of production increase for each unit of pressure drawdown at the face of the producing sand. Simply defined:

$$\text{P.I.} = \frac{\text{Fluid production}}{\text{Pressure drawdown}} = \frac{\text{Bbl. per day}}{\text{lb. per sq. in.}} = \frac{Q_2 - Q_1}{P_1 - P_2}$$

where:

Q_1 = production in bbl. per day at first rate,

Q_2 = production in bbl. per day at second rate,

P_1 = formation pressure at first rate, and

P_2 = formation pressure at second rate.

If the first condition is a static or shut-in run:

$$\text{P.I.} = \frac{Q_2 - O}{P_{static} - P_2} = \frac{Q_2}{P_{static} - P_2}$$

Productivity indices are generally determined with the aid of depth-pressure recording instruments. The procedure followed is to run a recorder in the well opposite the producing zone and the bottom-hole pressure for a given producing rate determined. The producing rate of the well is changed and the formation pressure recorded for the new rate. Thus, the four unknowns required for solving the productivity index relationship are available. Simple substitution is made in the equation:

$$\text{P.I.} = \frac{Q_2 - Q_1}{P_1 - P_2}$$

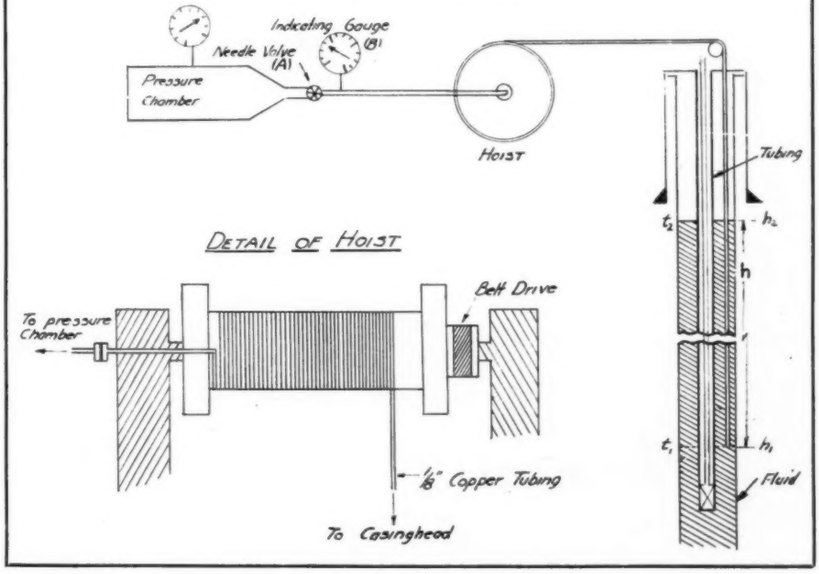
Integral Form

Productivity index can also be derived as an integral form involving rate of fluid rise in the well per unit time.

The derivation is based on the same fundamental conception but is carried through by substituting known relationships for the basic elements. By these substitutions productivity index (bbl. per day per sq. in.) is transformed to an integral form involving rate of fluid rise in the well with respect to time. The method outlined below derives the analytical procedure of determining productivity index by this method.

First, the quantity rate of production, Q, is the amount of production per unit time or:

Fig. 1. Fluid level determination by copper tubing method



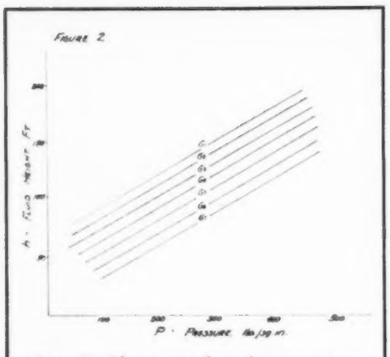


Fig. 2. Short-cut for determining fluid level

Q = bbl. per day = dq/dt.

Also:

$Q = z \times dh/dt$,

where:

z = a constant expressing the capacity of the flowing string in bbl. per ft., or z = bbl. per ft.

and, dh/dt = rise of fluid in string per unit time = ft. per day

Checking dimensionally:

$Q = z \times dh/dt$ = bbl. per ft. $\times$ ft. per day = bbl. per day.

The problem is to compute the rate of build-up with the fluid at any height, h. (See Fig. 4.) The formation is producing fluid at a rate:

$$Q = I \times \Delta P = I \times (H - h) \times G$$

where:

I = productivity index,

G = fluid gradient, and

H = static pressure expressed in ft. of fluid.

Or:

$$z \times dh/dt = I \times (H - h) \times G$$

$$dh/dt = I/z \times (H - h) \times G$$

Evaluating from points h_1 to h_2:

$$dt = \frac{\zeta\, dh}{I \times G \times (H - h)} \text{ or, } T = \frac{\zeta}{I \times G} \int_{h_1}^{h_2} \frac{dh}{H - h} = -\frac{\zeta}{I \times G} \int_{h_1}^{h_2} \frac{dh}{h - H}$$

Integrating:

$$T = -\frac{\zeta}{I \times G} \ln \left[h - H \right]_{h_1}^{h_2} = -\frac{\zeta}{I \times G} \left[\ln (h_2 - H) - \ln (h_1 - H) \right]$$

$$T = \frac{\zeta}{I \times G} \left[\ln (h_1 - H) - \ln (h_2 - H) \right]$$

$$T = \frac{\zeta}{I \times G} \ln \frac{H - h_2}{H - h_1}$$

$$\text{or, } I = \frac{\zeta}{T \times G} \ln \frac{H - h_2}{H - h_1}$$

$$I = \frac{K}{t_2 - t_1} \ln \frac{H - h_2}{H - h_1}$$

where:

K = a constant = $\frac{\zeta}{G}$

$T = t_2 - t_1$

Copper Tubing Method

The method of determining the static level of the fluid in a well by means of copper tubing is used constantly in water wells. The same method can be applied to an oil well.

The copper tubing is lowered to a known depth in the well by means of a hoist. The surface end of the tubing is connected to a pressure chamber containing compressed air or gas. (See Fig. 1.)

When the desired depth (h_1) is reached with the lower end of the tubing, pressure is slowly released into the tubing by means of a hand-operated valve, A. The air chamber pressure must be in excess of the fluid column measured from the bottom of the copper tubing to the fluid level or (h_1—h_2). The pressure in the tubing will build up to a value $P = h \times G$ and will remain at that value regardless of the volume of air released from the chamber.

As the depth of the lower end of the copper tubing is known from surface measurements, the fluid level is readily determined by reading the pressure indicating gauge, B, Fig. 1, and making a simple calculation as follows:

$P = h \times G$

where:

h = fluid height, ft.,

G = fluid gradient, lb. per sq. in. per ft., and

P = pressure, lb. per sq. in.

Or:

$h = P/G$.

It is not necessary, however, to perform the above computations each time a reading is taken. A short-cut is presented in Fig. 2. For any particular fluid gradient and pressure, the fluid height, h, is readily determined.

Summarizing, the fluid level is readily determined by reading the indicating pressure gauge and reading the corresponding value of h from the chart. The procedure is very rapid.

Fluid Gradient Determination

The method outlined requires that the fluid gradient in the well be known. This is also readily determined with the copper tubing pressure equipment. (See Fig. 3.)

Pressure readings are taken at two different depths. When this is done, however, care must be taken that the well is in a static equilibrium state; that is, at the conclusion of the regular measurements, as the well is near a static state.

The two pressure readings are taken as shown in Fig. 3. Points h_1 and h_2 should be at least 100 ft. apart. The two basic equations that apply are:

(1) For point h_1, $P_1 = h_1 \times G$

(2) For point h_2, $P_2 = h_2 \times G$

Subtracting equation (1) from (2) gives:

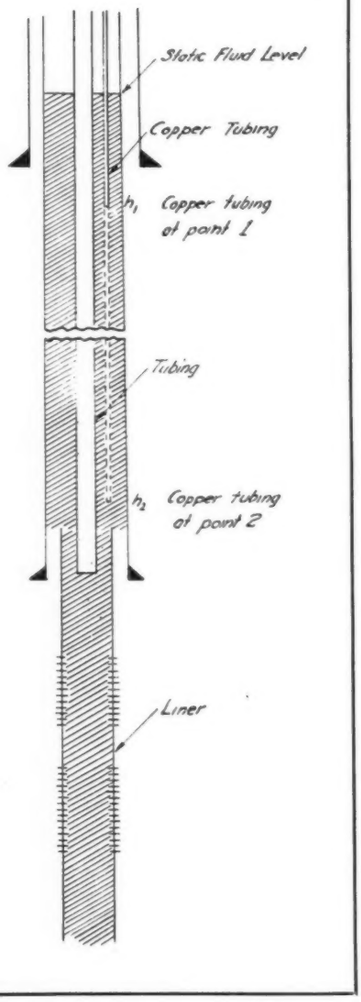
$P_2 - P_1 = h_2 \times G - h_1 \times G$

or:

$P_2 - P_1 = G(h_2 - h_1)$

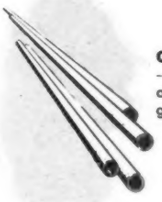
As $h_2 - h_1$ is known from measurements on the hoist at the surface, and, $P_2 - P_1$ read from the indicating pressure gauge directly, then:

Fig. 3. Determining fluid gradient



HOW *Longer-life Flupacos* CAN HELP IN WARTIME!

WILL *the pump you buy today still be on the job a year from now . . . and the next year . . . and the next?* If it's a new Flupaco pump, you can be sure of *longest* possible service, *least* possible maintenance, because these pumps today are outwearing many others as much as *5 to 1* under the toughest kind of pumping conditions. That's a performance point *vitally important* in your wartime pump maintenance program. Look at these Flupaco features:



ONE-PIECE BARREL
—entirely eliminates disadvantages of jacket-plus-liner construction, gives higher production efficiencies.

SPECIAL HEAT TREATMENT
—makes full-length barrel 4 to 8 times harder on its wearing surfaces, doubles and triples service life.

MIRROR-FINISH HONING
—insures smooth, effortless plunger operation in barrel under all kinds of pumping conditions.

PRECISION ALIGNMENT
—eliminates uneven stroking because of free plunger travel.

FEWER REPLACEMENTS
—simple design reduces bulk, cuts weight in many cases to one-fourth of other pumps, eliminates *all* unnecessary parts.

So for your long range production program today, use top-performance Flupacos, pumps that are replacing bulky, costly types and streamlining entire production operations. Long-lived Flupaco "Groove Seals" and "Improved Insert" Pumps are available in a range of sizes, types, and metals for all conditions—and they're just as economical to buy as they are to use. See your Fluid Packed Pump representative—or write us direct—today—for the full details!

FLUID PACKED PUMP COMPANY, BOX 64, LOS NIETOS, CALIFORNIA

2 S. E. 29th ST., OKLAHOMA CITY, OKLA. ★ HUNT BLDG., TULSA, OKLA. ★ 2301 CONGRESS AVE., HOUSTON, TEXAS

WORLD'S LARGEST EXCLUSIVE OIL WELL PUMP MANUFACTURER

FOUR TIPS

ON PUMP MAINTENANCE

to make present equipment last longer

1 Careful transportation:

Crate your pumps for long hauls, and handle carefully to avoid bending. Don't pile heavy objects on top of pumps, and make sure they are placed on a flat surface or are supported at close intervals. Wrap ends, but do not remove shipping or data tags.

2 Inspection:

After removing a pump from the well, clean it as quickly as possible to avoid unnecessary rusting. Lay pump flat on bench and inspect thoroughly. Check condition of pump anchor seat, and all accessible ball valves and seats. Use hydraulic pump to free sanded plunger. Use wrench flats provided when unscrewing parts, with end-wrenches to fit. Avoid applying excessive pressure or torque.

3 Repair and Reassembly:

Replace all worn parts with new ones, working with wrenches close to mating surfaces. Do not make up parts with excessive pressure—clean and lubricate threads first to avoid need for heavy strains. Make sure all valves are in proper position. When reassembled, tag and identify pump, giving all important specifications.

4 Systematic Storage:

Before storing, make sure all parts subject to rust are well oiled, greased or wrapped. Wrap accessories in moisture proof paper. Store so that pumps cannot be damaged.

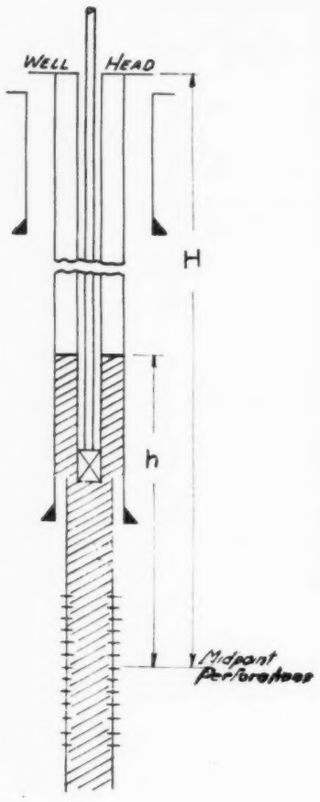


Fig. 4. Computing the rate of pressure build-up

$$G = \frac{P_2 - P_1}{h_2 - h_1}$$

= fluid gradient.

Application of Data

Application of pressure data obtained with the copper tubing equipment is made in determining indices by substitution in the integral form previously derived.

Up to this point, the copper tubing method is shown to give bottom-hole pressure at any given time, and at any desired depth in the well. Determination of productivity index using the integral form derived, requires two such measurements while the fluid level in the well is rising.

The running of copper tubing in the annulus between casing and tubing does not require removal of any part of the pumping equipment. The pumping operation of the well is not affected in any way.

Before the first pressure determination is made, the well is pumped for a period of time at a given rate, to lower the fluid level in the annulus to establish equilibrium. When equilibrium is reached, the pump is shut down and the first reading taken. Though only two readings are needed for the productivity index determination, several readings taken at short intervals of time is considered the best practice. The operation is very simple and speedy, hence the added accuracy afforded by several spaced readings is considered well worth the time. The time between runs depends upon the producing capacity or build-up rate of the well.

The pressure versus time values obtained are plotted as illustrated in Fig. 5. The plot represents the build-up curve of the well. The time required for the fluid level to rise from one level to a desired level is accurately scaled from the curve.

Substitution of Data

Sufficient data are now available from the h versus t curve to solve the previously developed integral productivity index relationship. Two sets of values for h and t are scaled from the curve and easily substituted in the formula:

$$\text{P.I.} = \frac{K}{t_2 - t_1} \ln \frac{H - h_2}{H - h_1}$$

where K and H are constants.

The values for t_1, t_2, h_1, and h_2 are taken from a representative part of the curve. The steepest portion of the curve is preferred because of the added accuracy afforded.

Summary of Procedure

The determination of the productivity index of a pumping well by the copper tubing method consists of the following steps:

1. Determination of build-up characteristics of well by measuring rate of fluid level rise in the casing after pump is stopped.
2. Fluid gradient determination by copper tubing method. This requires that the fluid level remain constant while two separate measurements at different depths are made.
3. Substitution of values for h_1 and h_2 in the integral formula for corresponding values of t_1 and t_2. Values for the four variables are scaled from the h versus t build-up curve.

Other Applications

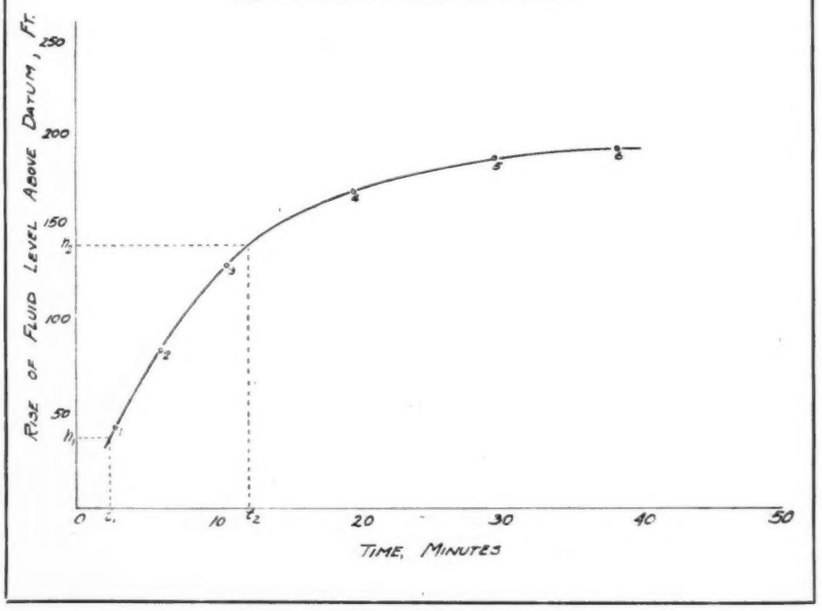
In many instances in production engineering work it is convenient to determine productivity indices when wells will not flow. That is, when the bottom-hole static pressure is not sufficient to raise fluid to the surface. This is particularly important in newly completed wells in areas of semi-wildcat character. Many times such wells test as potential producers but will not flow with continued swabbing.

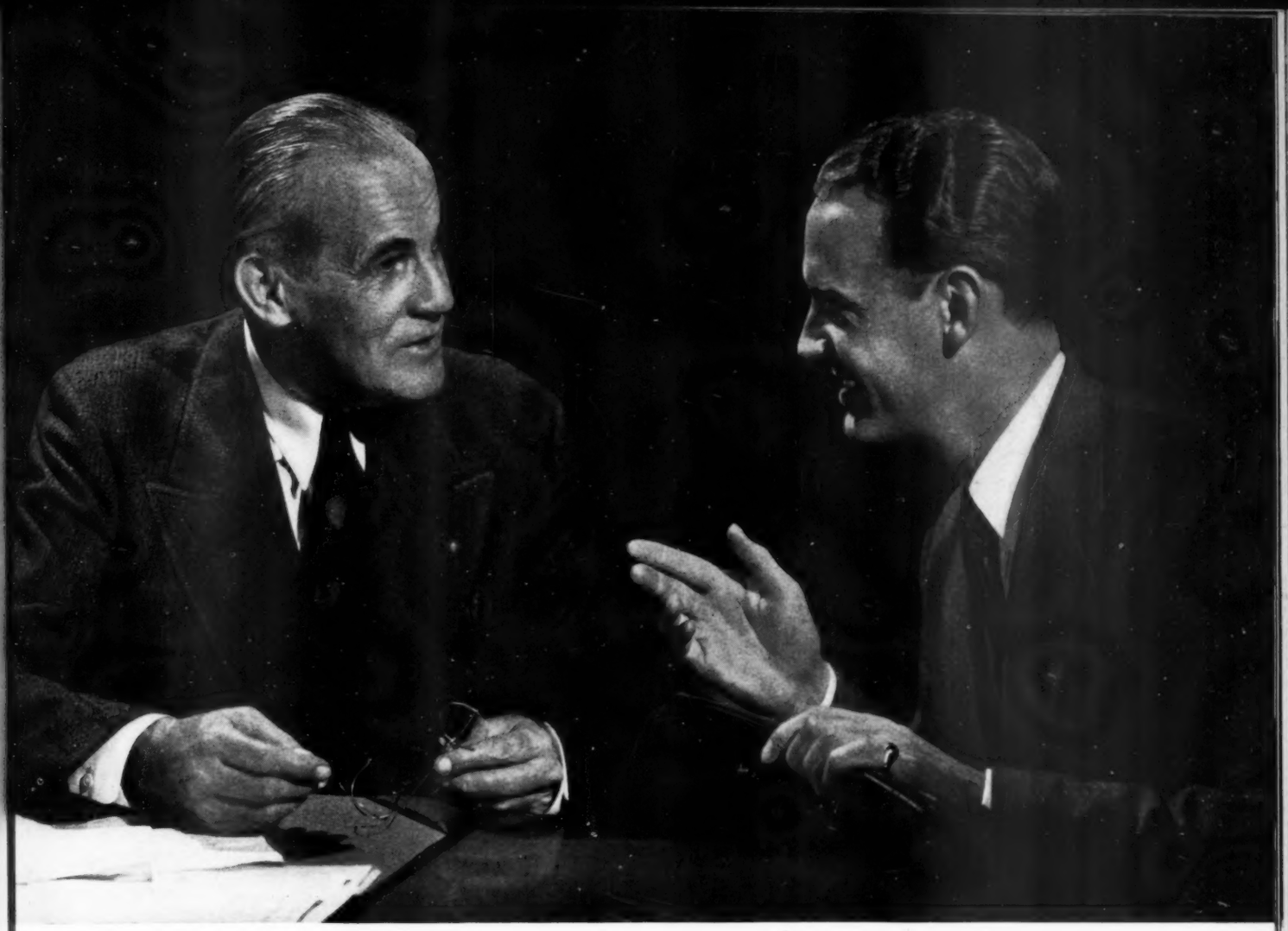
There then arises the question whether (1) the well is merely slow in attaining a flowing state due to a low permeability of the sand, (2) the drilling fluid has penetrated the formation clogging the pores, or (3) the productivity index is very low and the well must be placed on the pump immediately.

As the well cannot be made to flow naturally, a productivity index is not attainable by the ordinary methods. In such a case, the method of determining productivity index by means of measuring rate of rise of fluid level in the well over a period of time, may be used.

—— ☆ ☆ ☆ ——

Fig. 5. Pressure versus time values





"What! Even Better Casing To Come?"

Casing Buyer: You're right—Smith Casing *has* saved us real money. But can we get it now?

Smith Representative: No, right now you can't, because we've stopped making casing, perhaps "for the duration." Instead, we're producing war material with all our resources of men and machines. Helping to win this war is uppermost in the minds of the same research men, engineers, and production men who made Smith Casing so outstanding in economy and performance.

Casing Buyer: Performance . . . that's what made our boys in the field so enthusiastic about your product.

Smith Representative: And they'll see even better performance when the war is over and we can supply the *new* Smith Casing. We're learning a lot from our war production. Under pressure of emergency, great things are being discovered, perfected, and adapted to mass-production methods . . . things which our technicians can already see applied to peacetime pursuits. Mark my word—*out of today's experiences will come an even better Smith Casing!*

• • •

Offices at New York, Pittsburgh, Chicago, Tulsa, Dallas, Shreveport, Houston, Los Angeles, Seattle.

ELECTRIC-WELDED SMITH-WAY **CASING**

A. O. SMITH Corporation

MILWAUKEE • WISCONSIN

Oil Reservoir Drainage Increased by Intermittent Air-Injection

☆ Predetermined cycles of air-injection result in recovery of oil from oil pockets and semi-depleted sands

by F. R. Cozzens

District Field Manager, Equity Oil and Gas Company

ALMOST every producing sand contains quantities of oil that are sealed in pockets or reservoirs beyond the reach of producing wells. In areas where air-drive is practiced as a secondary recovery measure this condition is aggravated, because air, following a course of least resistance through the sand forces oil sidewise as well as forward; operators must practice fluctuating the pressure, staggering of input wells, and various other means to drain such pockets and to prevent the formation of new ones. From these practices, largely experimental, but conducted over wide areas and for a considerable period of time, have come promising discoveries in sand drainage. A recent one, which in many districts is being backed up by facts, is that oil reservoirs, not only on recovery projects but in virgin sands as well, can be drained by a type of erosion, brought about by the intermittent injection of air or gas.

Intermittent Injection

Intermittent injection, or the injecting of air under pressure into input wells in predetermined cycles is not new; the original purpose was to force air into "dormant" parts of a sand that are not affected by a continuous injection pressure. When a large volume of air is forced into porous sections of sand for a number of hours, and the pressure released for a like period of time, the air gradually filters or "bleeds" back into the more permeable channels, bringing with it oil and water containing considerable residue. This residue, commonly known as "floating sand" soon settles out, and upon examination is found to be made up of a cement-like material that forms the natural binder of the sand itself. When the air pressure is again applied, this fluid minus most of its residue is forced back into the so-called dormant pockets of the sand, returning again during the "off" interval with more residue. The action is similar to that in the violent jetting of water against a surface rock, which eventually becomes honeycombed and porous by the force and intermittent action. In a sand such honeycombing continues in several directions, and when the binder in the sand in the immediate area of an oil pocket or reservoir is removed by erosion, the accumulation of oil is released into more permeable channels and thus recovered. In practically every locality where intermittent air-drive is practiced, this action manifests itself by sudden increases in oil production in certain wells that may amount to several times the normal output. The volume of production increase and its duration depend upon the size of the reservoir that has been drained. In this manner, oil pockets and reservoirs in various parts of any producing formation may be tapped.

Eastern Methods

In the eastern stripper oilfields where intermittent air drive has been practiced and closely studied for many years, maximum air pressures of 100 to 400 lb. are generally recommended for most producing sands. To assure that all the air reaches a producing zone, packers are cemented at the top of the sand in input wells. The average cycle is 12 hours of air injection at maximum capacity and pressure, followed by an 8-hour rest, during which the pressure is released. The 8-hour "off" period provides a breathing spell during which the fluid settles back into the main channels, deposits its residue, and is again ready for re-injection into the dormant pockets of the sand. This intermittent injection is continued day and night while results on producing wells within the area are carefully studied. When a certain producing well responds by a sudden marked increase in oil production, air injection on input wells known to be serving the producing well is suspended temporarily, allowing a freer drainage of oil into the recovery area. As soon as the crest of production is passed, intermittent air injection is resumed on the regular schedule. Extremely hard sands usually require the maximum air pressure (350 to 400 lb.) at the beginning of the process, and many operators find it advisable to equalize the induction cycle by using a 12-hour injection period followed by a 12-hour release period. After the first week or ten days, pressure can generally be lowered somewhat, and the wells put on the regular 12- and 8-hour schedule. In districts where air-drive is already in use as a secondary oil recovery measure, intermittent injection is adopted without any radical changes in equipment, stationary air compressors being utilized to supply the necessary pressure of air. In districts where secondary recovery is not practiced, a portable compressor, usually oil-engine-driven and capable of delivering the required air pressure, must be installed. When portable or similar light air-compressor units are used, the sand to be treated must be limited in extent, comprising on an average one input well and two or three producing wells, for efficient results. The area and extent of injection can be changed as conditions warrant.

Value of Method

Oil pockets and reservoirs, containing hundreds of barrels of oil have on various occasions been tapped and recovered, but most of the reservoirs are of much smaller capacity. The time required to reach and tap dormant areas within a reservoir depends to a great extent upon the sand texture, and also injection pressure and the operator's patience. Continued practice of intermittent air injection invariably brings results that in most cases repay well the effort involved. Repeated tests, conducted in various eastern fields, have proved also that intermittent injections of air are more beneficial to most sands than the continuous application of a steady pressure. Due to the progressive increase in extent of sand thus affected, the operator adds to his possibility for reaching more oil pockets in the reservoir, and consequently may increase the effectiveness of his air-injection operations.

—— ☆ ☆ ☆ ——

WITH A MISSION PISTON YOU GET LONGER UNINTERRUPTED SERVICE

ADVANCED DESIGN AND TOUGHER RUBBER COMPOUND GIVE MISSION PISTON RUBBERS EXTRA LONG LIFE

Extra long piston rubber life brings longer runs between replacements, and less slush pump shut-down time.

Then, after a long, uninterrupted run, you renew the piston by simply installing new rubbers without even removing the piston from the rod. Furthermore, you save the cost of the piston body (about half the cost of the entire piston).

Guaranteed: Proved long life and low replacement cost enables us to guarantee Mission Pistons to be the most economical on the market to operate.

Thousands of operators all over the world have found that Mission Pistons speed up drilling by improving slush pump performance.

WITH MISSION, YOU "CHANGE THE RUBBERS AND SAVE THE PISTON"

USE ALL MISSION PUMP PARTS— They work together for best all-round performance.

MISSION MANUFACTURING CO.

HUMBLE ROAD, HOUSTON, TEXAS

EXPORT OFFICE: 30 ROCKEFELLER PLAZA, NEW YORK

Drilling in Swamp Area of Louisiana Gulf Coast Simplified by Use of Barges

Exclusive

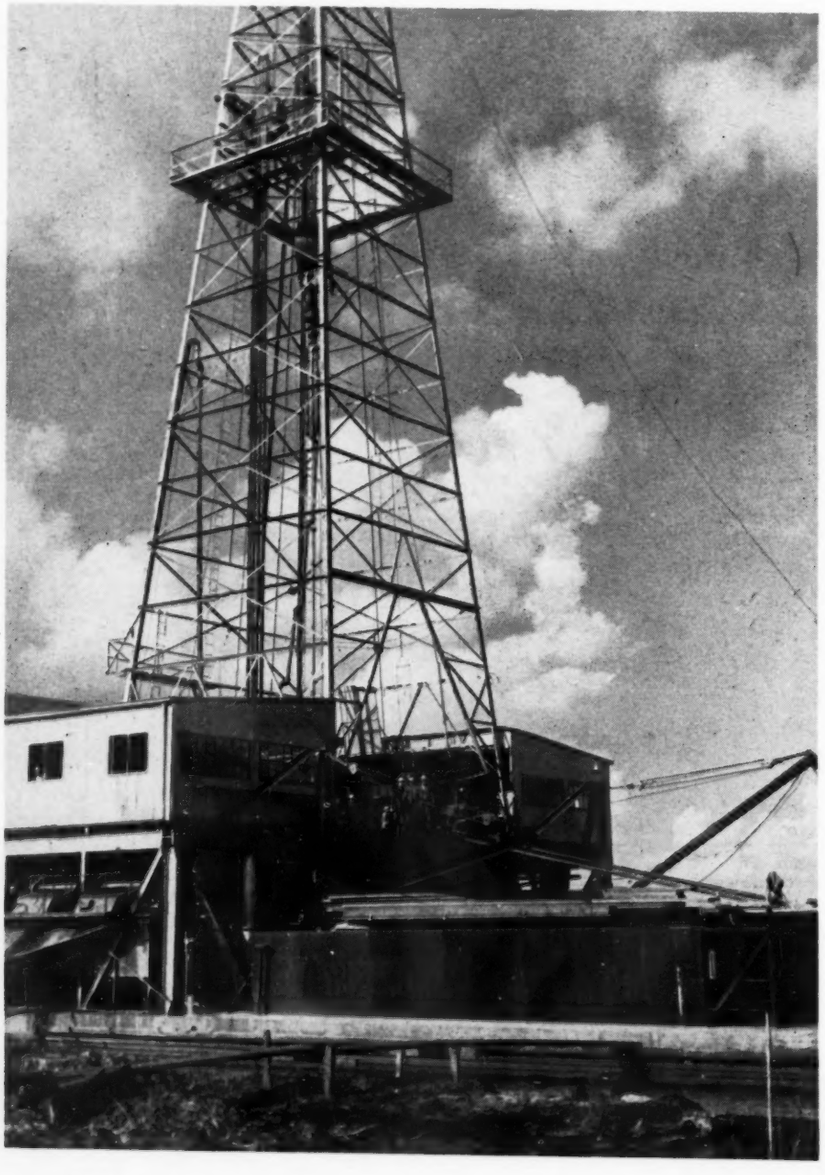
☆ Practicability of large-type units demonstrated under severe operating conditions

by C. C. Pryor
Associate Editor

THE submersible drilling barge has been in use for a number of years and has become an accepted method of drilling in certain areas, particularly in those difficult of access in the coastal waters of Texas and Louisiana. Obviously, there are numerous designs and types of drilling barges suitable for various location such as swampland through which canals have been dredged, open water in lakes and bays, etc. The drilling barge herein described has been employed in drilling both in open water in the bays along the Gulf of Mexico and in swamplands.

This barge is typical of the wide improvement that has been attendant on deeper drilling where heavy equipment operating under the severest of conditions is utilized.

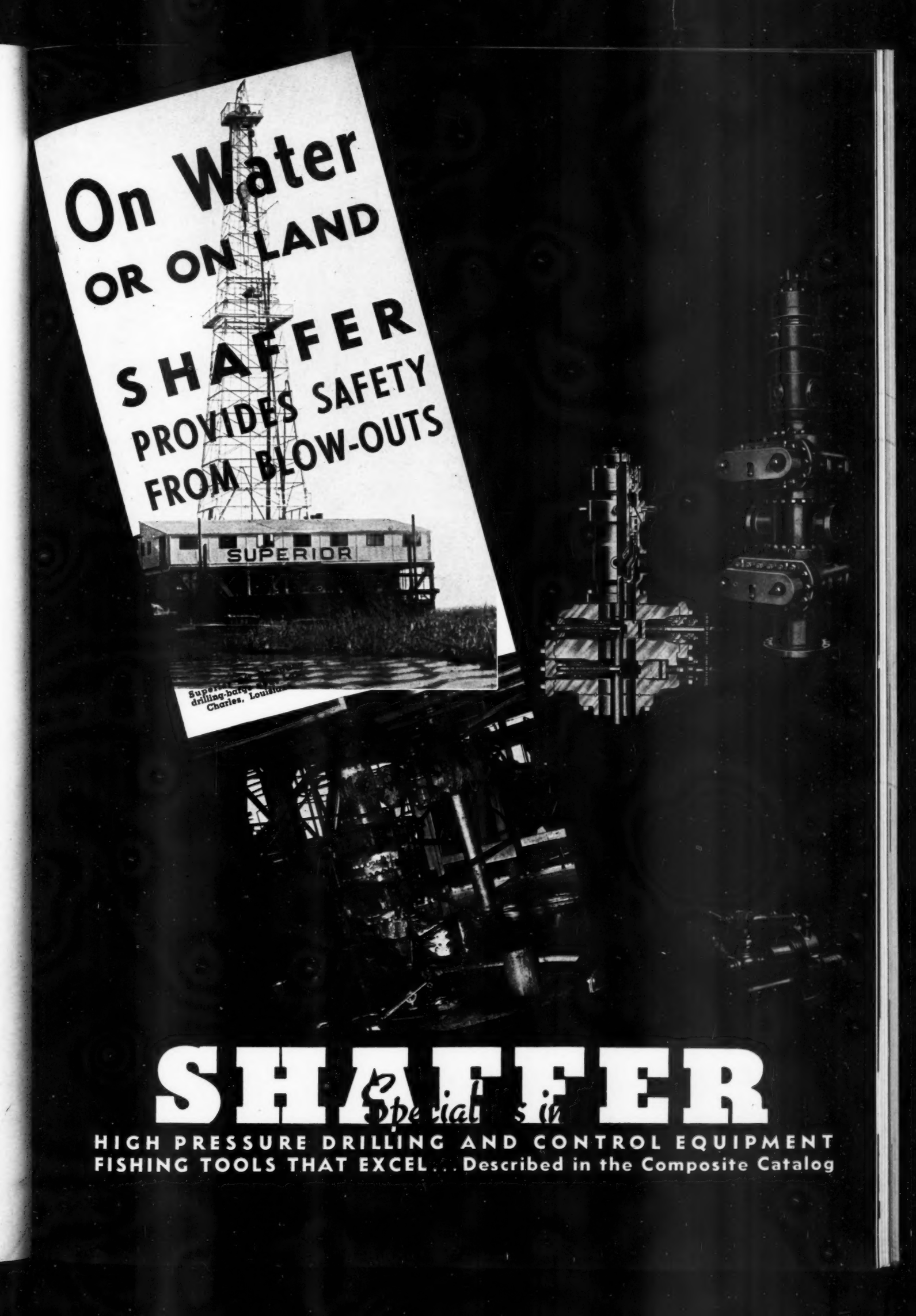
Unusual features of the barge are its large size and the compactness and accessible arrangement of equipment.



General view of drilling barge. Heavy steel beams are used in substructure

Twin-Hull Drilling Barge

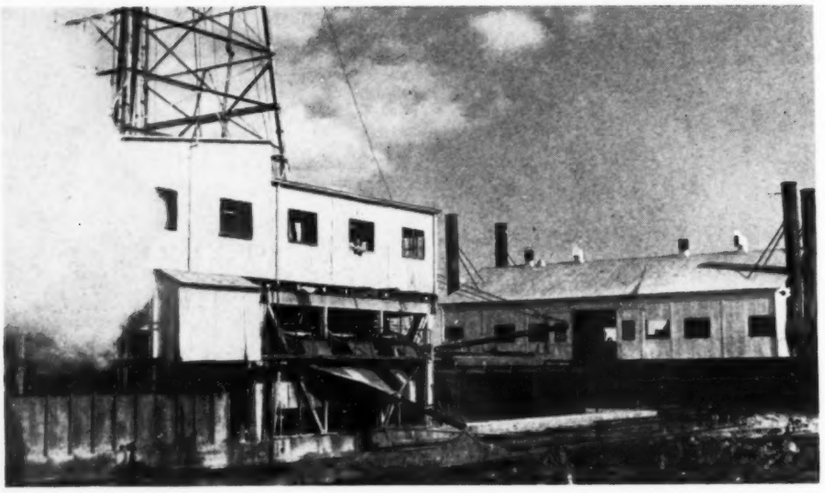
The main unit of the rig or drilling barge consists of two barges 10 ft. deep, 145 ft. in length, and 32 ft. in width. When over the location for a well, the two barges are situated one on each side of two rows of 6 piling each, marking the location of the well. The barges are then joined by two transverse trusses. After being joined, the two barges are sunk to the bottom, forming a level platform of more than 10,000 sq. ft. The structural steel framework of the barges is covered with ½-in. welded steel plate on the sides, and ⅜-in. plates on the bottom. The deck is of 5/16-in. plate. Each barge is divided into six compartments, which are flooded to sink the barge on location. This compartment-type construction is typical of marine vessels, guarding against the entire barge being sunk when the plates of one compartment are ruptured. Generally, it is not necessary to prepare a level setting for the barge. Most locations in dredged canals, lakes, and bays are suitably near level. The weight of the barge usually displaces the silt in settling on the bottom, preparing its own level setting; however, should listing occur, lightening the proper number of compartments will level the barge deck. Joined together the barges have a gap, or space, between them of 8 ft. The 136-ft. derrick having a capacity of 800,000 lb. is erected with two legs on each barge with the V toward the front of the unit. When moving from one location to another, under conditions that require separation of the twin hulls, the derrick must be dismantled. The nar-



SHAFFER

Specialists in

HIGH PRESSURE DRILLING AND CONTROL EQUIPMENT
FISHING TOOLS THAT EXCEL... Described in the Composite Catalog

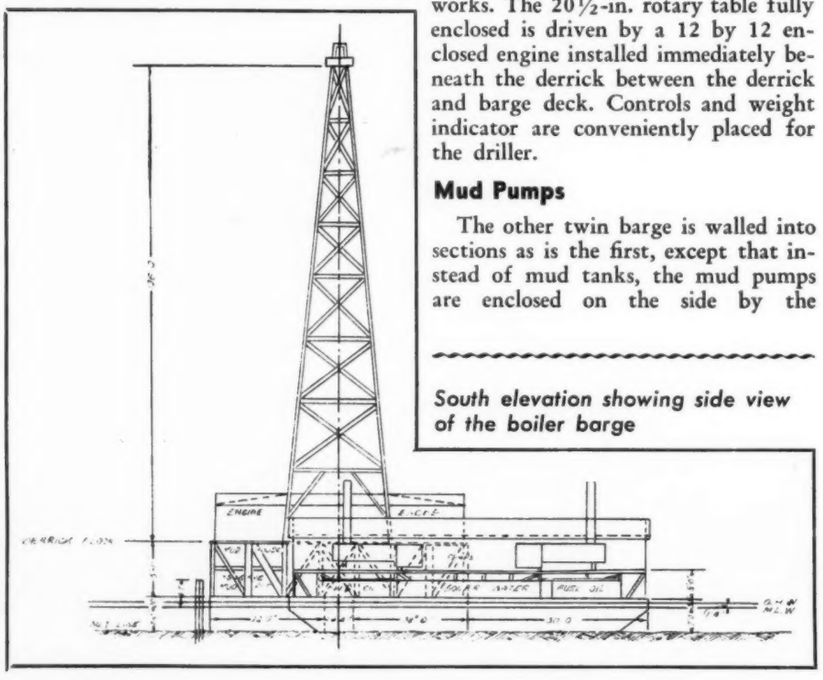


Shale shakers on main barge with completely housed boiler barge in background

row width of the two barges permit them to be towed through narrow channels or canals. This feature represents a considerable saving in dredging canals or channels to locations, as a narrow channel is sufficient. Obviously, it is necessary that the twin hulls be completely balanced when taken apart for towing to another location.

Equipment

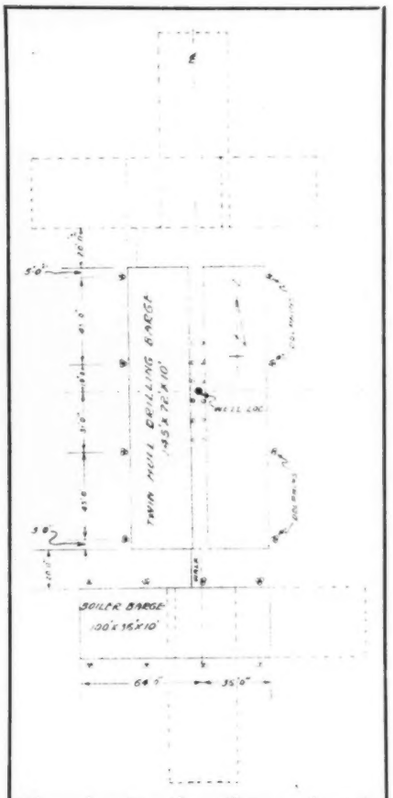
There is no equipment placed in the hull of the barges, as the various compartments are flooded when the barges are sunk on location for drilling. One barge has the mud pit, conditioning mud pit, and mixing equipment in square tanks with 8-ft. walls of steel plate. This equipment is mounted on the rear deck of the barge and the two mud tanks have a capacity of about 600 bbl. each. The walls of the tanks permit the barge to be sunk on location in water that is deep enough to rise above the deck without damage to equipment. Similar tanks for fuel oil, water, or reserve mud are mounted on the deck at the front of the barge. These front tanks are roofed and carry one-half of the pipe rack on top. The upper deck (derrick floor level) of this barge is 15 ft. above the barge deck and contains the tool and spare equipment room and the main drawworks and engine. The drawworks is fully enclosed and complete with hydromatic brake, disengaging coupling brake, high-speed cathead, and high-speed hoist. A 14 by 14 twin enclosed drilling engine is situated behind the drawworks. The 20½-in. rotary table fully enclosed is driven by a 12 by 12 enclosed engine installed immediately beneath the derrick between the derrick and barge deck. Controls and weight indicator are conveniently placed for the driller.



South elevation showing side view of the boiler barge

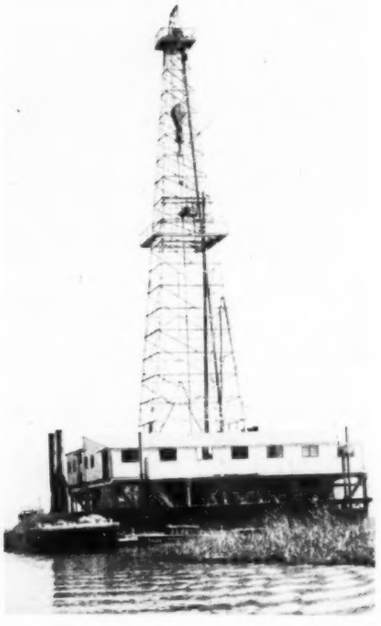
Mud Pumps

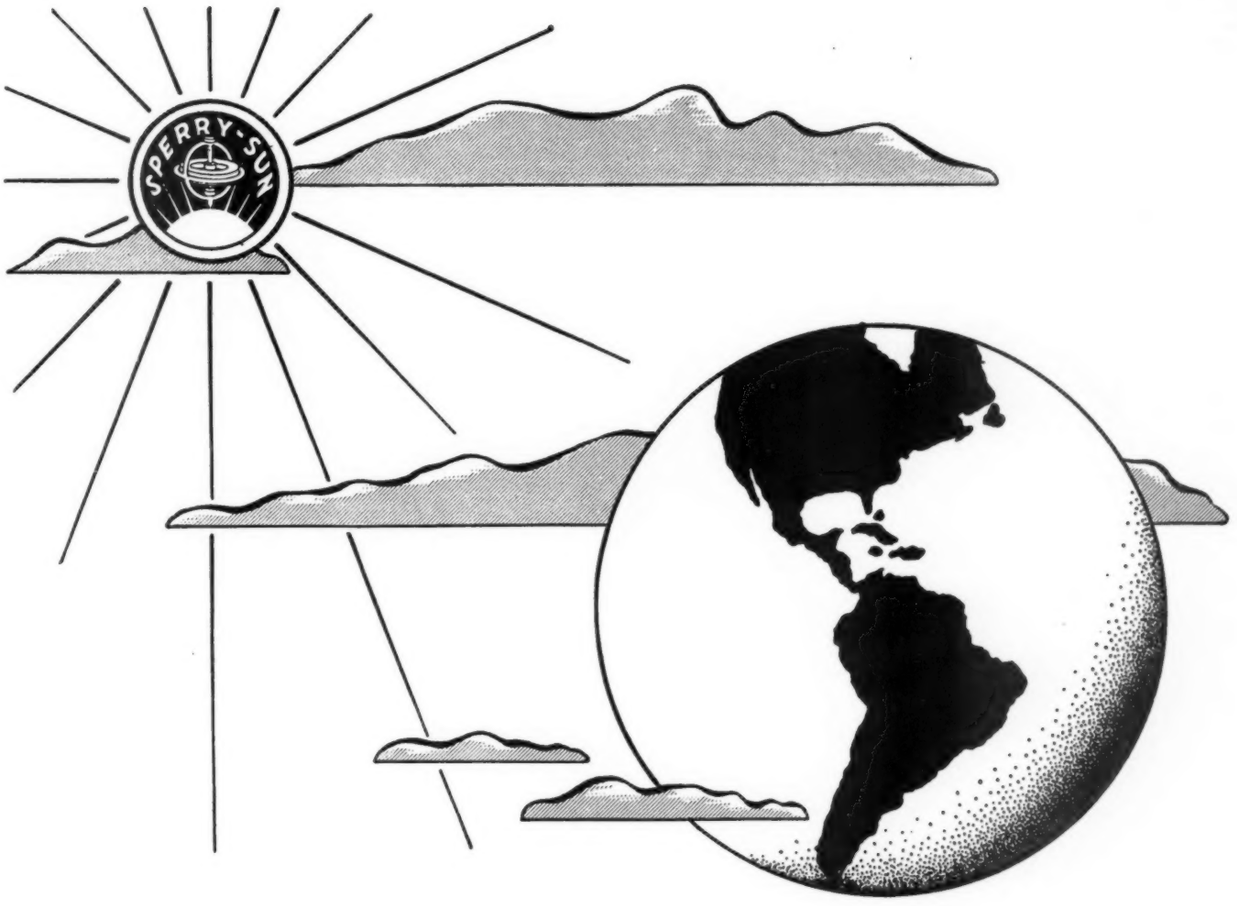
The other twin barge is walled into sections as is the first, except that instead of mud tanks, the mud pumps are enclosed on the side by the walls of steel plate. The mud pumps are three 15½ by 8½ by 20 and may be used in conjunction or individually



Plan showing the piling and position of barges with respect to well location

General view from the rear of the barge





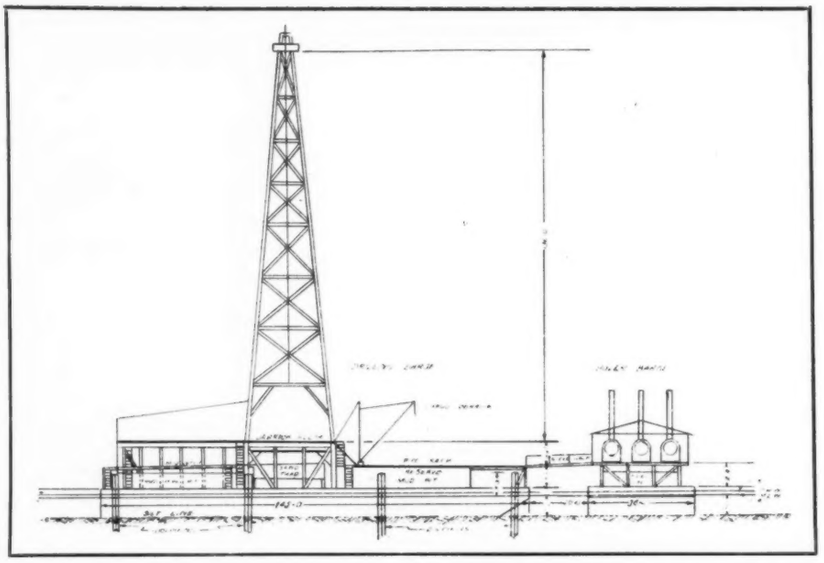
The Sun Never Sets on SPERRY SUN

Sperry-Sun Well Surveying Instruments and Services are in successful operation in all parts of the globe, performing accurately and economically.

SURWEL Clinograph	**H-K Inclinometer**
Syfo Clinograph	**M-M-O Bottom Hole Orientation**
E-C Inclinometer	**K-K Whipstock**
H-K Single Shot	**Polar Core Orientation**

SPERRY-SUN WELL SURVEYING CO., 1608 WALNUT ST., PHILA., PA.

Houston, Texas - Corpus Christi, Texas - Lubbock, Texas - Fort Worth, Texas - Odessa, Texas - Lafayette, La. - Long Beach, Calif. - Bakersfield, Calif. - Oklahoma City, Okla.



West elevation of the drilling barge

by a manifolding arrangement. As the mud pumps are mounted on one of the twin-hulled barges and the mud tanks on the other, the connections from the pumps to the tanks are made with 12-in. lines, bridging the slot between barges with heavy-duty fabricated rubber hose. The pumps are also used to pump the water from the barges' compartments to raise them for moving. This is accomplished by valves that switch the suction of the pumps from the tanks to the compartments. The shale shakers, driven by steam turbines, are in the center of the barge on the side immediately beneath the standby equipment to facilitate the disposal of cuttings and sand. This location permits the return of mud to the mud tank by gravity. There is a reserve mud tank or water tank on the front of the barge with the second half of the pipe rack above it. On the second floor or deck of this barge are the crew's quarters, laboratory, and standby drawworks and engine. The standby unit consists of a drawworks, a sand reel upper drum attachment, and a 12 by 12 enclosed drilling engine.

Cargo derricks to facilitate loading and unloading of pipe are on each barge at the corner of the derrick structure. Heavy steel I-beams are used in construction of the substructure of the upper or derrick floor.

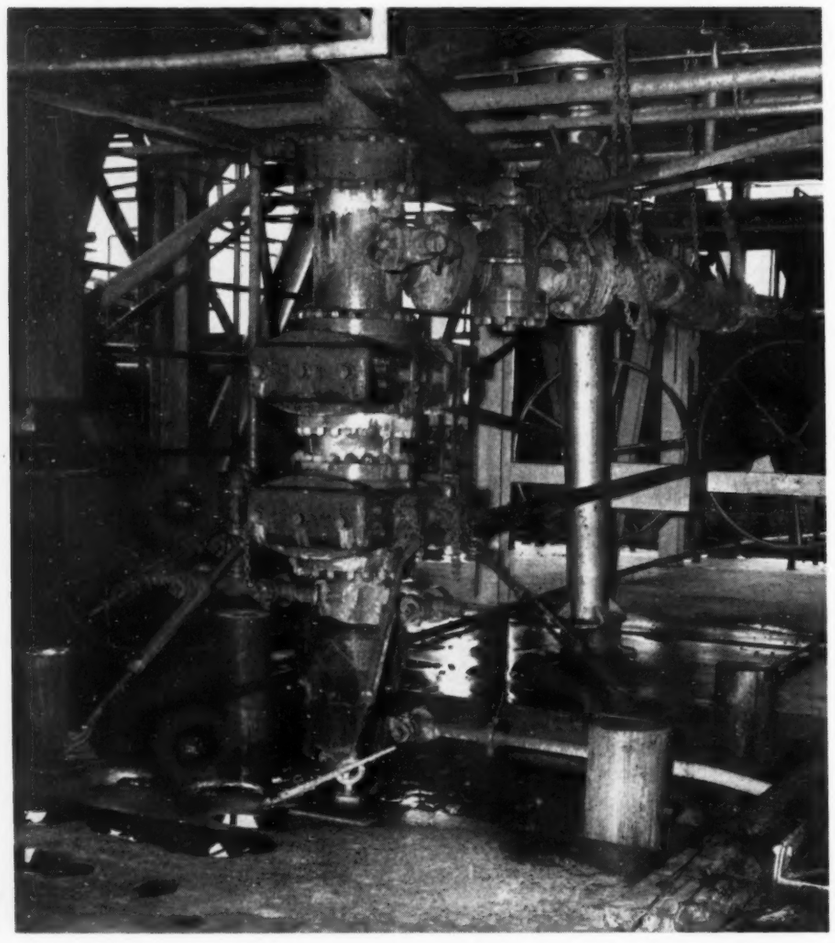
The Boiler Barge

As may be seen from accompanying photographs, the boiler barge is completely housed in a corrugated sheet metal structure. The boilers, feedwater heater, pumps, and control panel are all on an upper deck level 8 ft. above the barge deck. The boiler barge is 100 ft. by 36 ft. by 10 ft. In open water the boiler barge is sunk in position between 8 dolphins as an aid in preventing shifting. Tanks beneath the upper deck serve as storage space for fuel oil and boiler water. Total draft of the barge when floating is decreased by carrying the fuel oil for the boilers in a tank on a smaller barge. With this arrangement it is not necessary to transfer the oil to the main storage tanks and the smaller barge is easily towed to a loading terminal, refilled, and returned to the location.

Five boilers supply steam for the drilling engines, pumps, turbines, etc. The boilers supply superheated steam at a working pressure of 350 lb. per sq. in. The feedwater heater has a capacity of 90 bbl. and is equipped with a chemical treating attachment. Two of the boilers are mounted at one end of the barge with the feedwater heater between them. The remaining three boilers are mounted on the other end. On some locations the boilers may be fired with natural gas. They are converted easily from gas to fuel oil. Fuel pumps and feedwater pumps are mounted in the center of the barge with the control panel at one side in the center. There is a marine type condenser on the rear of the drilling barge cooling water for which is taken from the canal.

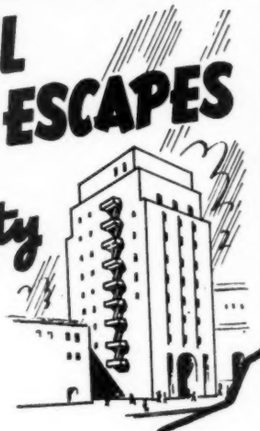
Generators to supply current for lighting and other general use are installed near the boiler pumps.

—— ☆ ☆ ☆ ——



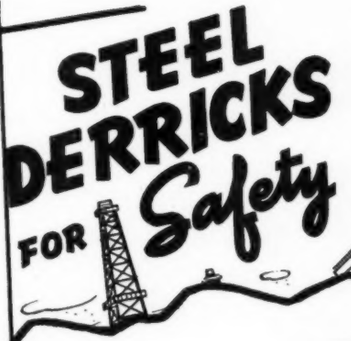
The blowout preventer. Note the method of tying down

STEEL FIRE ESCAPES FOR Safety

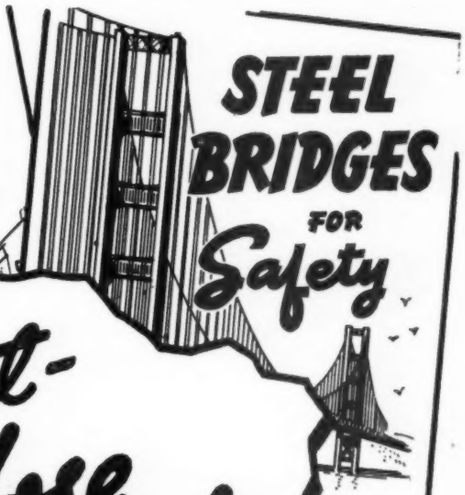


. . . not because the builde
. . . but because the occ
safety. Drillers use CHI
Rotary Ho

STEEL DERRICKS FOR Safety



STEEL BRIDGES FOR Safety



ffic loads
igher and

We repeat—
Steel Hose for Safety!

STEEL HULLS FOR Safety

BANKS U
STEEL
VAULTS
FOR
SAFETY

Banking experience proves that valuables are safer behind walls and doors of steel. Likewise, drilling experience proves that operations are safer when CHIKSAN **All-Steel** Rotary Hose is used.

LONG-LIVED FLEXIBILITY

Neither age nor climatic conditions can shorten the e or reduce

Back in '39, when this series of advertisements appeared, material shortages were unheard of. Safety was important then, when both materials and manpower were plentiful. Safety is doubly important today, when men and materials are invaluable. Incidentally, CHIKSAN All-Steel Rotary Hose purchased then is still strong and safe today.

STEEL TURRETS

ety

ttleships go
ble . . . but

PLAY SAFE!

3" For Standby for Pressure or Oil Circulating Service
4" and 5" Sizes for Drilling
45'- 50'- 55'- 60' Standard Lengths
Special Lengths to Order
The flexibility of CHIKSAN All-Steel Rotary Hose is not affected by climatic conditions

GULF ENGINEERS, INC.
Distributors in Texas, Louisiana, Arkansas and New Mexico

WELL EQUIPMENT MFG. CO.
Distributors in Oklahoma and Kansas

CHIKSAN TOOL COMPANY
CHIKSAN
BALL BEARING SWING JOINTS for ALL PURPOSES
BREA, CALIFORNIA
ALL-STEEL ROTARY HOSE
CIRCULATING HEADS · MUD GUNS

STEEL CARS

FOR Safety

u wouldn't buy a car with a wood
y and a fabric top . . . because
el has replaced wood and fabric.

Bonding Pipe Lines as Protection Against Electrolysis

PETROLEUM ENGINEER Exclusive Feature

☆ Types of bonds and methods of installation discussed

by E. E. Claggett

Research Department, Southern California Gas Company

ELECTROLYSIS and its influence on the maintenance of underground pipe lines is now well recognized by anyone who has anything to do with pipe-line operation. The various electrical influences that may affect a buried line are fairly well known and in order to combat the evil effects of these currents leaving the pipe, bonds or cables may be connected to the pipe to serve as a path over which a current may be carried to a place where it may be harmlessly discharged.

The more important of these electrical influences are:

(1). Stray or vagrant currents. These are due to leakage from some current-carrying device in the earth (such as an electrical railway rail) to a pipe line that is not designed to carry current but is close enough to offer another path for the current.

(2). Galvanic electricity. This is caused by the pipe traversing several kinds of soil, thus setting up a galvanic cell that establishes a potential and causes a current to flow.

(3). Static electricity. This is generated in the more open stretches of country usually traversed by long pipe lines. The wind blowing across the country causes friction between sand and dust particles that generate static electricity, which is picked-up by the pipe lines.

(4). Magnetic fields. The constantly shifting magnetic fields in the earth often cross the path of pipe lines and a part of their energy is carried along by the pipe. This source of current will come more and more to the attention of the engineer as instruments and equipment are perfected to detect it.

The bonds or cables being used to carry electrical currents from pipe lines to places of harmless discharge are of various types. The conditions encountered and the adaptability of the bond to meet the requirements will govern the selection of the kind to use. A considerable part of the discussion of bonds and testing installations pertains to natural gas distribution systems in cities and other congested areas where piping problems are difficult.

E. E. CLAGGETT

was born in Washington, D. C., September 26, 1907—His first job after graduating was with a public utility company supplying electric power to several eastern states—Since 1930 has been associated with The Los Angeles Gas and Electric and Southern California Gas Companies—Has been in the research department of the latter company since 1937, engaged in electrolysis work.

Jumper Bonds

Jumper bonds are generally used around a rubber gasket coupling to make a continuous path around an insulating or high-resistance joint and are usually buried completely.

Rubber gasket couplings in a pipe line may be placed at frequent intervals or may be long distances apart. When they are closely spaced it is often best to take advantage of their insulating effect to break up the flow of current in the pipe line.[1] If a rubber gasket coupling is some distance from another one it may cause joint electrolysis by forcing the current to leave the pipe and form a path around the coupling through the earth. In this case a jumper may be installed to carry the current around the coupling.

There are several kinds of jumper. The one to be used depends on the desire of the engineer to achieve full pipe conductivity, or any degree of resistance, by the selection of the material used. The simplest jumper is a mild steel rod, welded across the coupling, and covered with asphalt and kraft paper in the same manner as an ordinary field wrapped joint (Fig. 1). Minimum rod sizes and dimensions are given in Table 1.

When it is desirable to obtain full pipe conductivity for large-diameter pipe or to keep the potential drop across the coupling as low as possible, it is recommended that a copper jumper be used. Copper equivalents of steel pipe are given in Table 2. Second-hand 3/0 trolley wire that has been annealed is recommended for this and other bonding purposes, because as many

TABLE 1
Typical coupling dimensions

Pipe Dia. Nom., in.	Middle Ring			Flanges		Bolts			Gasket Section		Overall Length "B" in.	Jumper Rod	
	L in.	L' in.	t in.	Outside Diam., in.	Thickness in.	No.	Diam., in.	Length, in.	Y in.	X in.		Dia. Rod, in.	"M" min., in.
1	5	4½	0.134	4¼	0.375	2	½	6¾	9/32	9/16	7¼	⅜	6
1¼	5	4½	0.134	4⅞	0.375	2	½	6¾	9/32	9/16	7¼	⅜	6
1½	5	4½	0.165	4¹⁵/₁₆	0.375	2	½	6¾	11/32	⅝	7¼	⅜	6
2	5	4	0.1875	6⅛	0.250	3	⅝	8	½	23/32	8½	⅝	8
3	5	4	0.250	7½	0.250	4	⅝	8	½	23/32	8½	⅝	8
4	5	4	0.250	8⅞	0.250	4	⅝	8	½	23/32	8½	⅝	8
6	5	4	0.250	10⅝	0.250	6	⅝	8	½	1	8½	⅝	10
8	5	4	0.250	12¹¹/₁₆	0.250	6	⅝	8	½	1	8½	¾	10
10	5	4	0.250	14¾	0.250	8	⅝	8	½	1	8½	¾	12
12	5	4	0.250	16⅞	0.250	8	⅝	8	½	1⅛	8½	¾	12
16	7	6	0.3125	20½	0.3125	10	⅝	10½	½	1⅛	11	¾	12
20	7	6	0.375	24⅝	0.3125	12	⅝	11	⅝	1⅜	11½	1	14

HOW TO GET THE MOST OUT OF THE ROTARIES YOU NOW HAVE!

SAVE MATERIALS

As a saver of materials, the "Oilwell" Rotary Drilling Unit is now an essential item of machinery on a steam rig. ★ It greatly reduces wear-and-tear on the expensive drawworks and big hoisting engine by doing away with their use for the 80 per cent of the total drilling time devoted to rotation. ★ The complete elimination of rotary chain and sprockets saves substantial sums otherwise required for repairs and replacements. ★ Bits give better footage due to the more accurate control of the drill string. ★ And, the rotary itself gives longer service as a result of smoother operation and less severe shocks and strains.

SAVE TIME

Independent rotary operation by means of a compact and quiet-running shaft-drive from an "Oilwell" No. 7 (7¾"x7") or No. 9 (10"x9") Vertical Twin-Cylinder Steam Engine results in increased drilling speed and flexibility. ★ The driller has accurate control of the drill string at all times. He can raise and lower the bit at will while rotating at any desired speed. ★ The driller can step up the table to the highest speeds with comparative safety.

The drilling unit lessens the danger of twist-offs; and the absence of noise enables the driller to detect instantly changing conditions in the hole. ★ The drilling unit cuts time on round trips by speeding up the breaking-out of drill pipe. ★ In case of failure of the draw-works or hoisting engine, the driller can continue to rotate the string and thus avoid sticking the drill pipe. ★ In emergencies the drilling unit engine can be used for hoisting, or the hoisting engine for drilling.

SAVE POWER

The "Oilwell" Rotary Drilling Unit saves power by eliminating the use of the big hoisting engine for driving the rotary, an operation which normally takes up 80 per cent of the total drilling time. The smaller and highly efficient cut-off controlled vertical steam engine on the drilling unit operates at a much more favorable load factor in this service. Tests show savings of as high as 30 per cent in the fuel and feedwater required for rotation.

Use Your Present Rotaries

The "Oilwell" Oilbath and Super-Speed Rotaries you now have can be assembled on available frames with new gear boxes and engines to provide you with modern "Oilwell" Rotary Drilling Units. Inquire at the nearest "Oilwell" store or office.

Speeding-up the breaking-out of drill pipe and stacking pipe on the floor space released by elimination of the chain drive are only two of the many advantages of "Oilwell" Rotary Drilling Units.

OIL WELL SUPPLY COMPANY

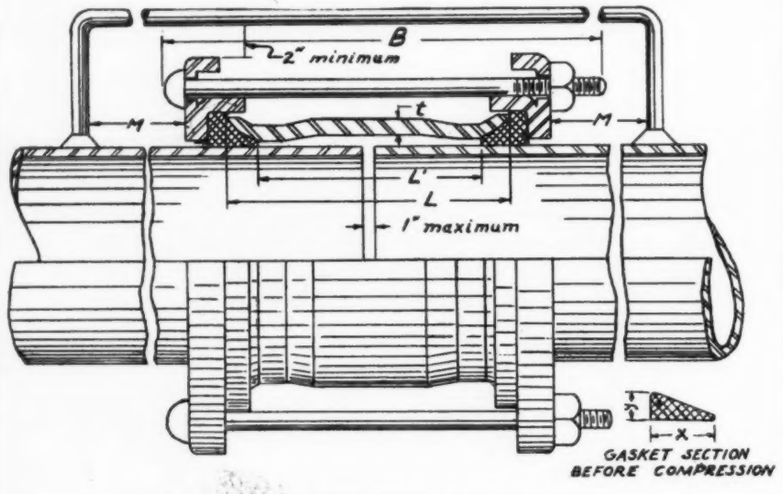


Fig. 1. Typical coupling with iron rod jumper

strands as necessary can be made into a cable to provide the desired circular mil cross-sectional area. Moreover, the cost is moderate compared with new copper. Owing to the fact that copper must be brazed to steel pipe, the copper-brass-iron couple thus formed must be heavily coated to prevent galvanic action.[2]

The method illustrated by Fig. 2 has been found very satisfactory. After the size of wire has been determined, the proper lengths are cut and bound into a cable. On each side of the rubber gasket coupling 1 ft. is allowed to prevent the welding torch from burning the rubber gasket and 8-in. on each side to clear the coupling properly. The cable is bent to 90° at the 8-in. mark and the ends fanned out to ¾-in. or 1-in. centers and brazed to the pipe. A 2½-in. standard iron elbow is pushed over the cable to the bend; a 12-in. fiber nipple is then screwed into the elbow and is followed by two fiber couplings and another 12-in. fiber nipple with the threaded end in the opposite direction. This is followed by a 2½-in. iron tee.

These parts are pushed as close to the elbow as possible and the other end is bent to 90° at the other 8-in. mark and brazed to the pipe. The tee is then pushed back to the bend, the 12-in. nipple is screwed into the tee, and the fiber couplings made-up. The space left in the middle is then filled with a fiber nipple, split lengthwise, which is placed around the cable and held together with wide friction tape. The ends under the elbow and tee are covered with 6-in. lengths of 4-in. fiber conduit, split lengthwise, and held together with friction tape.

The open end of the tee can be used to carry a potential test wire to a permanent test point. The entire length of conduit is then filled with hot asphalt, using the length of conduit protruding from the tee as a pouring boot.

Tie Bonds and Drainage Bonds

Tie bonds are used to equalize the potential between two underground structures, one or both of which may be pipe lines. The tie bond may be buried completely or may be brought to the surface in a suitable box for testing. If the bond connects the structures of two different companies it is usually advisable to make the connections available from the surface.

Drainage bonds carry the current away from the pipe to a place where it may be discharged safely. This may be a substation negative bus or some cathodic protection device. The bond may be run aerially by means of a pole system or underground through conduits,

TABLE 2

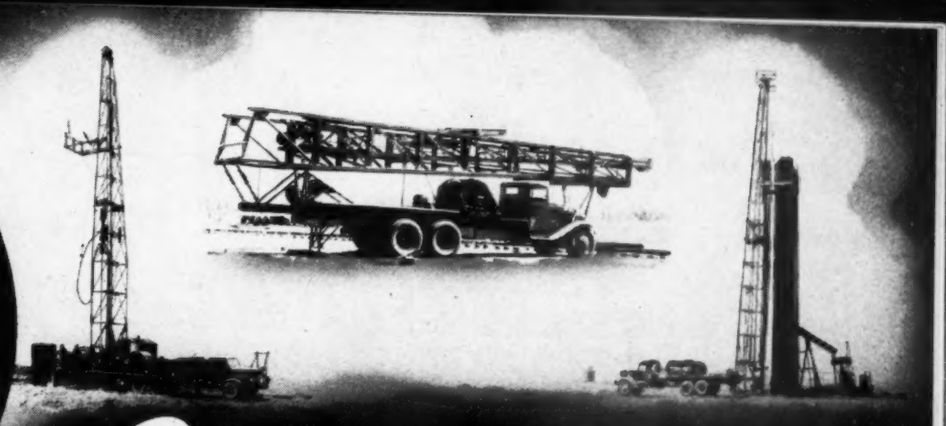
Copper equivalent of wrought iron pipe—conductivity
Transverse areas

Nominal diameter, in.	Metal, sq. in.	Circular mils, iron	Equivalent circular mils, copper	Stranded or solid cable no.
⅛	0.07	89,126	14,854	9
¼	0.12	152,788	25,464	6
⅜	0.17	216,450	36,075	
½	0.25	318,309	53,051	3
¾	0.33	420,168	70,028	
1	0.50	636,618	106,103	0
1¼	0.67	853,068	142,178	2.0
1½	0.80	1,018,589	169,764	3.0
2	1.07	1,362,363	227,060	4.0
2½	1.71	2,177,234	362,872	
3	2.24	2,852,049	475,341	
3½	2.68	3,412,274	568,712	
4	3.18	4,048,892	674,815	
4½	3.68	4,685,510	780,918	
5	4.32	5,500,381	916,730	
6	5.59	7,117,392	1,186,232	
7	6.92	8,810,797	1,468,466	
8	7.28	9,269,162	1,544,860	
8	8.41	10,707,919	1,784,653	
9	10.04	12,783,295	2,130,549	
10	9.21	11,726,508	1,954,418	
10	10.01	12,745,098	2,124,183	
10	11.94	15,202,444	2,533,740	
11	13.40	17,061,370	2,843,561	
12	12.88	16,399,286	2,733,214	
12	14.59	18,576,521	3,096,086	
13	16.05	20,435,446	3,405,907	
14	17.23	21,937,866	3,656,311	
15	18.41	23,440,285	3,906,714	
Outside diameter				
16	12.37	15,749,936	2,624,989	
16	15.40	19,607,843	3,267,973	
16	18.41	23,440,285	3,906,714	
20	15.51	19,747,899	3,291,316	
20	19.33	24,611,662	4,101,943	
20	23.12	29,437,229	4,906,204	
22	17.08	21,746,880	3,624,480	
22	21.29	27,107,206	4,517,867	
22	25.47	32,429,335	5,404,889	
24	18.65	23,745,861	3,957,643	
24	23.26	29,615,482	4,935,913	
24	27.83	35,434,173	5,905,695	
26	20.22	25,744,843	4,290,807	
26	25.22	32,111,026	5,351,837	
26	30.19	38,439,011	6,406,501	
30	23.37	29,755,538	4,959,256	
30	29.15	37,114,845	6,185,807	
30	34.90	44,435,956	7,405,992	

Based on the following equation:

$$\text{Cir. mils of copper} = \frac{\text{Metal, sq. in.} \times 10^6}{0.7854 \times 6}$$

With copper having six times the conductivity of iron.



TO Really Save STEEL, MONEY and LABOR Specify

100% PORTABLE RIGS and SERVICING UNITS

Carrying their own Derricks

SAVE UP TO 25% PER WELL BY USING FRANKS TRUCK-MOUNTED RIGS FOR DRILLING UP TO 5000 FEET

A Franks truck-mounted drilling rig, complete with derrick, drawworks, pumps, power plant, rotary table, swivel, kelley, crown block, stacking board and all essential equipment costs approximately one-half as much as the cost of the old type drilling rig with comparable equipment. Add to the *savings* in original cost—*savings* in labor (Franks rig operates efficiently on a three-man crew); *savings* in fuel and water; *savings* in casing program (Franks rig is built for "slim-hole" economy); *savings* in rig-up, tear-down, and moving (Franks rig is permanently hooked-up with even the lines and blocks permanently strung)—and it is easy to see how you can *save 25%* or better by using a Franks 100% portable truck-mounted drilling rig.

SERVICE UP TO 100 WELLS FOR 1/4 TO 1/10 AS MUCH WITH A FRANKS TRUCK-MOUNTED SERVICING UNIT

One Franks 100% portable truck-mounted telescoping derrick servicing unit will do all the servicing necessary on 50 to 100 wells. To maintain 50 to 100 wells the old way, with permanent equipment at each location, costs from $100,000 to $250,000. Yet, one Franks unit—complete with double drum winch, portable self-raising and lowering derrick capable of pulling doubles, power plant, and location-to-location transportation, costs but $25,000 to $30,000—1/4 to 1/10 as much in equipment alone.

If you have 16 wells or more to service from the shallowest to 10,000 feet you can save money and steel by using Franks servicing units.

Daddy of economy in drilling and servicing, Franks Manufacturing Corp. is proud that it pioneered 100% portable equipment which today is saving much needed material, fuel, and man power for our war effort.

Franks pioneered "slim-hole" drilling rigs which afford savings in steel casing as well as in money.

Franks pioneered truck-mounted rigs and servicing units which eliminate the need of many auxiliary trucks thus saving tires and transportation vehicles.

Franks pioneered rigs and servicing units which carry their own self-raised and lowered derricks thus eliminating the need of thousands of tons of steel in permanent derricks as well as facilitating faster location-to-location moving.

See the Composite Catalog or write for further information on how you can save money for yourself, and vital materials for our war effort.

FRANKS MFG. CORP.

WELL SERVICING AND DRILLING UNITS

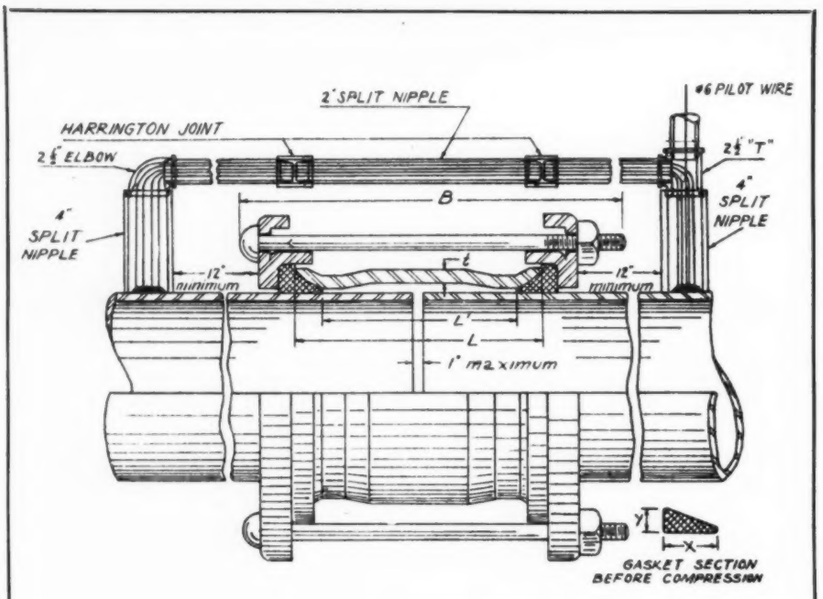


Fig. 2. Typical coupling with copper cable jumper

whichever is the more convenient and economical.

Tie bonds and drainage bonds are made-up of the desired number of strands of 3/0 trolley wire, brazed to the pipe or to a welded lug such as that shown by "A" in Fig. 4. This has the same current carrying capacity as a 4/0 wire and is enclosed in a fiber conduit filled with hot asphalt.

Pilot Wires and Deadmen

Pilot wires are used for test purposes only to obtain the potential of the structure not influenced by the drop caused by the flow of current. Potential test wires are brazed to a lug, as shown by "B" of Fig. 4, which is in turn welded to the pipe. (See Fig. 3.) The wire is run to the surface in fiber conduit, filled with hot asphalt. The lug serves as an anchor for the conduit and keeps the brazed joint under a solid asphalt cover. When it is desired to install a "deadman," i.e. earth electrode (Fig. 3), a 4-ft. section of 4-in. junk pipe is used. A ½-in. by 2-in. by 6-in. mild steel lug (See "A" in Fig. 4) is welded to the deadman and bent in the middle to 90° as indicated in Fig. 3. A No. 6 wire is then brazed to the lug and the wire extended to the surface in a fiber conduit filled with hot asphalt. The lug serves as an anchor for the fiber conduit and keeps the weld and braze under a solid asphalt cover.

The No. 6 copper, medium hard drawn, triple braid weatherproof wire is used for pilot wire to insure a permanent installation. Wire of this size and stiffness has adequate mechanical strength and the size is sufficient to prevent its being burned off when it is brazed. The weatherproof covering affords a more permanent protection than rubber covering.

Lugs

The lugs shown by "A" and "B" in Fig. 4 are made of mild steel bar and round stock. "A" is made from ½-in. by 2-in. by 6-in. mild steel bar, flattened at one end to allow the conduit to pass over it. "B" is ½-in. round mild steel, 6-in. long, flattened at one end to make a better surface for brazing the test wire.

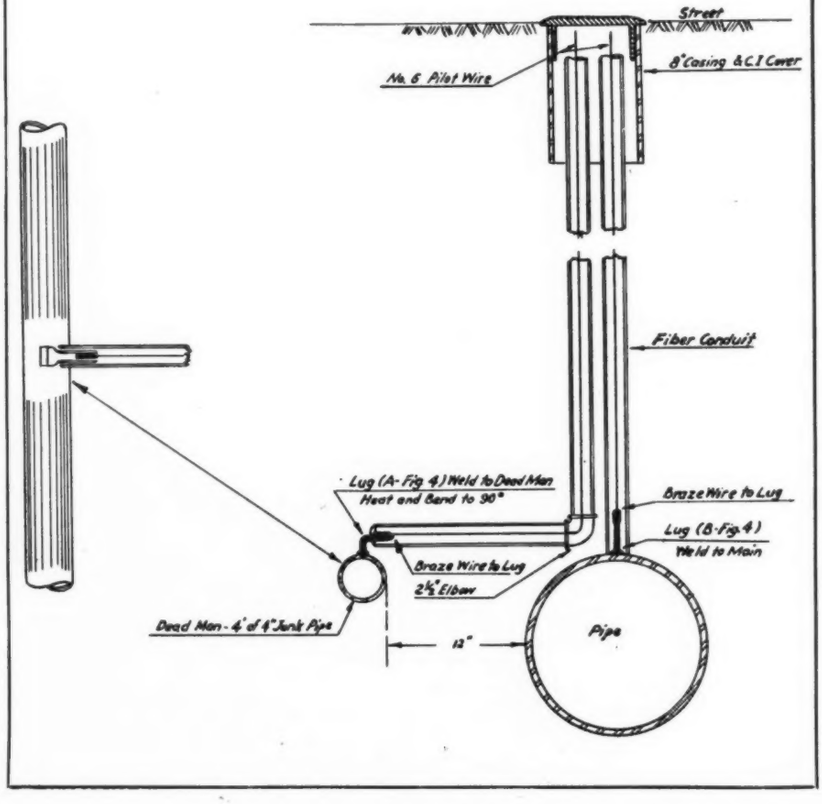
These lugs are recommended whenever it is necessary to connect a copper wire to a pipe. The lug serves as an anchor for the fiber conduit, as well as to keep the copper and brass away from the pipe, where possible galvanic action would result and where it can be covered in a solid mass of asphalt.

Test Points

Two methods of termination for test wires and cables are used. One is a standard 8-in. casing with a cast-iron cover (Fig. 3) placed directly above the installation of the deadman and the pilot wires, with the pilot wires terminating in the casing at ground level. This type of test point is used for tests requiring only indicating meter readings.

The other type of test point is a con-

Fig. 3. Method of installing test point



BAKER OIL TOOLS, INC.

Main Office and Factory:
6000 So. Boyle Ave., Box 127, Vernon Station, Los Angeles, Calif.
Central Division Office and Factory:
6023 Navigation Blvd., Box 3048, Houston, Texas
Export Sales Office:
19 Rector Street, New York, N. Y.

General Heading

BAKER MODEL "K" CEMENT RETAINER

Unit No. A-11

Subject

Index: 250.1
Date: July 1, 1942
Page: 1 of 1 P.

Squeeze Cementing as an Economical Solution to Many Well Repair and Well Completion Problems

One of the oil industry's most important responsibilities today is to see that each and every well be capable of maximum production for the longest possible period of time, with a minimum expenditure of ***time, money and materials.***

In this connection, "squeeze cementing" as a safe, economical solution to many well repair and well completion problems becomes increasingly important.

Thousands of such jobs have been successfully performed with the Baker Model "K" Cement Retainer, and details of two such typical jobs are given herein.

If you are confronted with water problems, or other well repair or completion problems, which may be solved through the use and proper placement of cement, check on the results other operators have secured with the Baker Model "K" Cement Retainer.

You can obtain details from any Baker Office or field representative.

For complete details concerning design, construction and operation of the Baker Model "K" Cement Retainer, see pages 250-263 of the 1942 Baker or Composite Catalog.

Product No. 400

Baker Model "K" Cement Retainer

BAKER MODEL "K" CEMENT RETAINER APPLICATIONS

Recementing
Cementing Behind Sections of Pipe
Reducing Gas/Oil Ratios
Plugging Off Bottom Fluids
Plugging Back to Upper Zones
Testing Upper Cased Formations
Squeeze Jobs
Cementing Off to Perforate for Production
Cementing Bad Pipe
Cementing Two Strings Together
Cementing Low-Pressure Zones
Use of Cement Retainer as Casing Bridge Plug

Service Note

Competent Baker men will service, make suggestions, and otherwise assist in securing best possible results.

JOB NO. 1

PROBLEM:

To Repair Split in Casing Through Which Shale Was Entering and Hampering Pumping Operations.

METHOD:

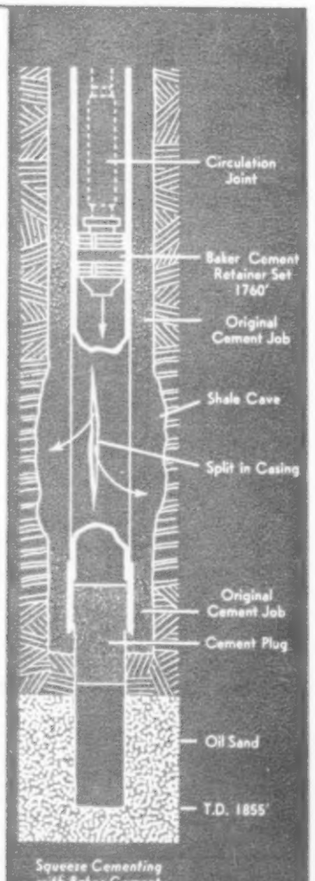
Set Baker Cement Retainer above Casing Split and Do Squeeze Job. (A Cement Bridge was Placed at Top of Producing Zone.)

RESULT:

100% Successful.

*** DETAILS ***

Field: *Salem, Illinois*
Depth of Well: *1855'*
Depth Retainer Set: *1760'*
Breakdown Pressure: *800 lbs.*
Final Pressure: *1000 lbs.*
Number of Sax Mixed: *30*
Number of Sax Put Away: *30*
How Cement Discharged: *Through Casing Split in Shoe Joint*



Squeeze Cementing with Baker Cement Retainer to Repair Casing Split

JOB NO. 2

PROBLEM:

To Reduce Gas/Oil Ratio in a Field Where Normal Ratio is 60,000:1.

METHOD:

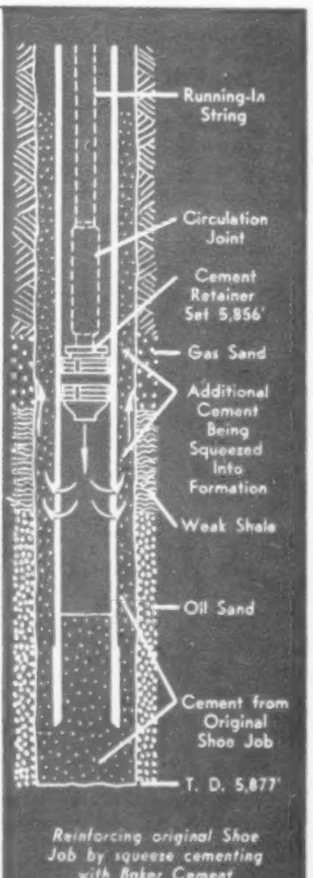
Before Well Completion Perform a Squeeze Cement Job with Baker Cement Retainer.

RESULT:

Well Completed with Gas/Oil Ratio of 550:1.

*** DETAILS ***

Field: *Grapeland, Texas*
Depth of Well: *5877'*
Depth Retainer Set: *5856'*
Breakdown Pressure: *1500 lbs.*
Final Pressure: *5000 lbs.*
Quantity of Cement Mixed: *125 sax*
Number of Sax Put Away: *13*
How Cement Discharged *Through 20 shot perforations in Shoe Joint*



Reinforcing original Shoe Job by squeeze cementing with Baker Cement Retainer to insure exclusion of free gas.

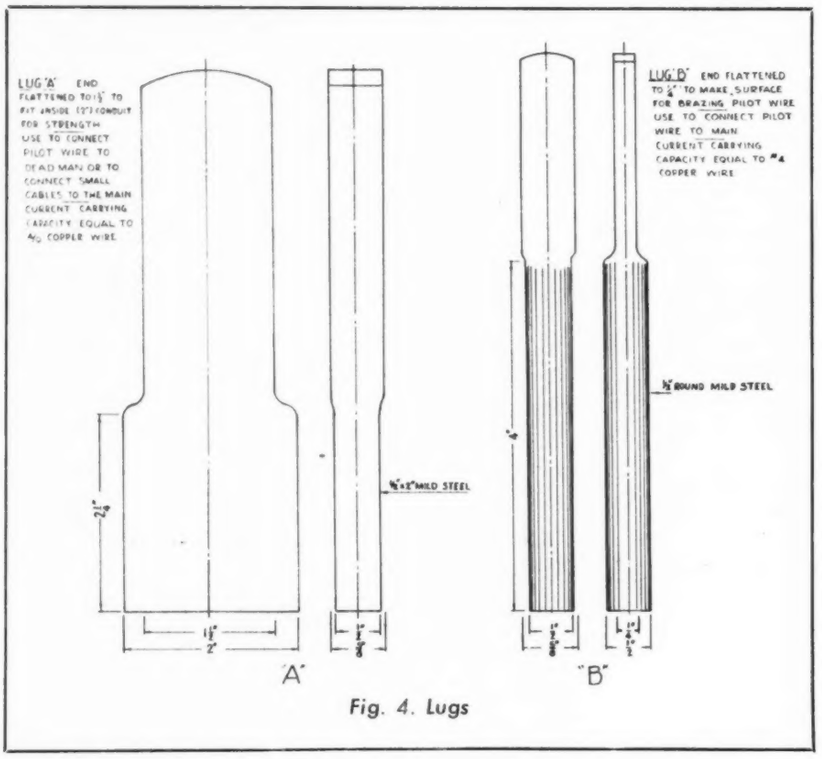

LUG 'A' END FLATTENED TO ½" TO FIT INSIDE 1½" CONDUIT FOR STRENGTH USE TO CONNECT PILOT WIRE TO DEAD MAN OR TO CONNECT SMALL CABLES TO THE MAIN CURRENT CARRYING CAPACITY EQUAL TO #6 COPPER WIRE
LUG 'B' END FLATTENED TO ¼" TO MAKE SURFACE FOR BRAZING PILOT WIRE USE TO CONNECT PILOT WIRE TO MAIN CURRENT CARRYING CAPACITY EQUAL TO #4 COPPER WIRE
½" ROUND MILD STEEL
½"x2" MILD STEEL
A
B

Fig. 4. Lugs

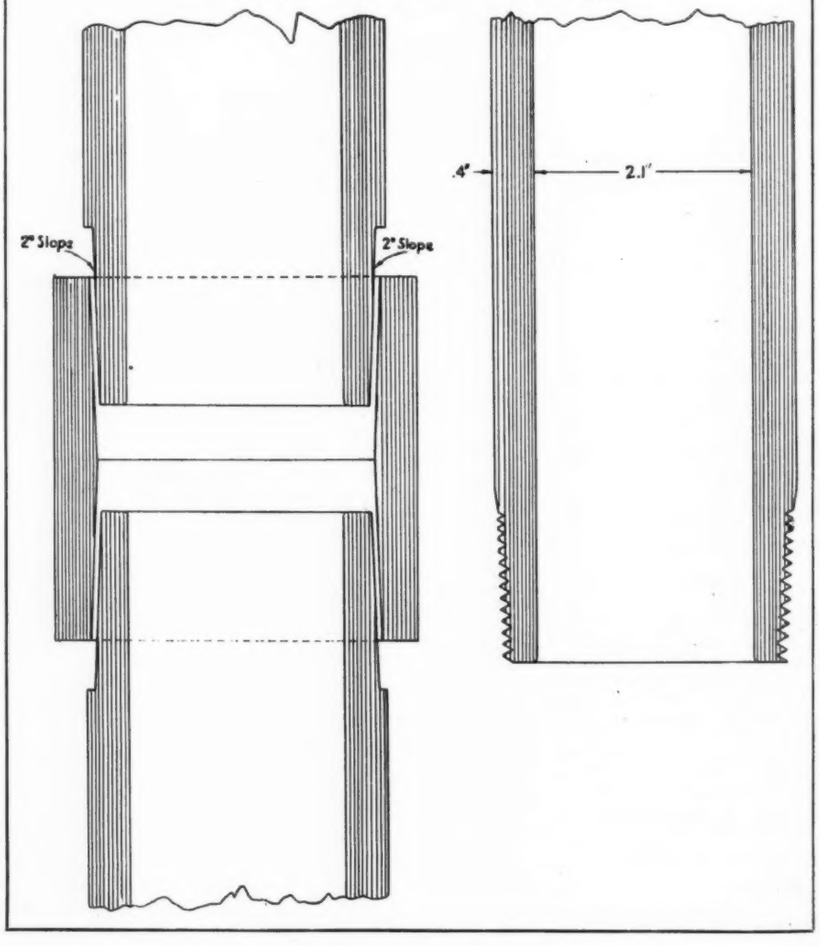
crete curb meter box, usually set in the parkway, which serves as a terminal point for the pilot wires, cables, and conduits. This type of box will hold four recording millivoltmeters. All wires are run in fiber conduit and filled with hot asphalt.

Conduit

The conduit[3] selected by the Southern California Gas Company as a protective covering for bonds and pilot wires is made of fiber because it appears to possess more of the desirable characteristics for underground work than any of the other materials examined. This conduit will not absorb more than 2 percent water by weight; has a crushing strength of not less than 3000 lb. per linear ft. making it safe to use under ordinary soil loads, and even under a pneumatic tamper; has excellent dielectric qualities; is said to be immune to soil corrosion, acids, and alkalies; can be purchased in 5-ft. lengths that may be joined by a fiber coupling, (Fig. 5) and has enough play in the joints to allow some curvature over several joints. Conduits of this fiber are easily installed, even by inexperienced labor, because the material is handled like any metal pipe, eliminating the necessity of having a carpenter build a wooden box that in time will disintegrate and leave the asphalt or bond exposed to the soil.

The conduit[4] is made of approximately 24 percent felted wood fiber and 76 percent coal tar pitch. The tube is formed and dried, then impregnated with coal tar pitch under 28 to 29 in. vacuum. The tube is easily cut with a carpenter's wood saw, using water as a lubricant, and can be worked on a lathe without the use of a lubricant. The standard 5-ft. lengths are converted into nipples of 6-, 12-, 15-, 18-, and 24-in. lengths in the company's own shop. One end is tapered to 2° and the other end cut to a standard 2½-in. pipe thread (Fig. 5) for connecting to 2½-in. pipe fittings. To the best of the writer's knowledge, the Southern California Gas Company is the originator of the idea of cutting threaded nipples from this material.

Fig. 5. A 2½-in. pipe thread on fiber nipple

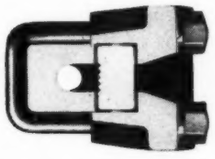


Bibliography

1. "Introduction and Elimination of High Resistance Pipe Joints for the Elimination of Electrolysis," by W. R. Schneider, P.C.G.A. Proceedings, 1937, Vol. 28, p. 77.
2. "Soil Corrosion Observations," by C. P. de Jonge, P.C.G.A. Proceedings, 1937, Vol. 28, p. 81.
3. Paper on Orangeburg Nocrete Fiber Conduit, by G. L. Wilder, General Electric Supply Corporation, January 24, 1939.
4. Paper on Orangeburg Nocrete Fiber Conduit, by F. P. Combier, Fiber Conduit Company, January 17, 1939.

☆ ☆ ☆

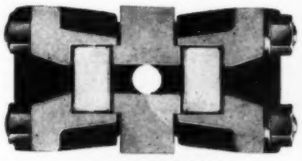
Alike in Quality



PENBERTHY *Reflex*
DROP FORGED STEEL
LIQUID LEVEL CAGES

Liquid shows black—empty space shows white. Preferred wherever liquid level must be easily and positively visible... and when liquids are under high pressure or at high temperature.

These gages are made of alloy temperature resisting steel and are the highest quality throughout. Liquid chamber is made from a solid block of steel to assure perfect alignment and rigidity. All Penberthy gages conform with A.P.I.-A.S.M.E. requirements.



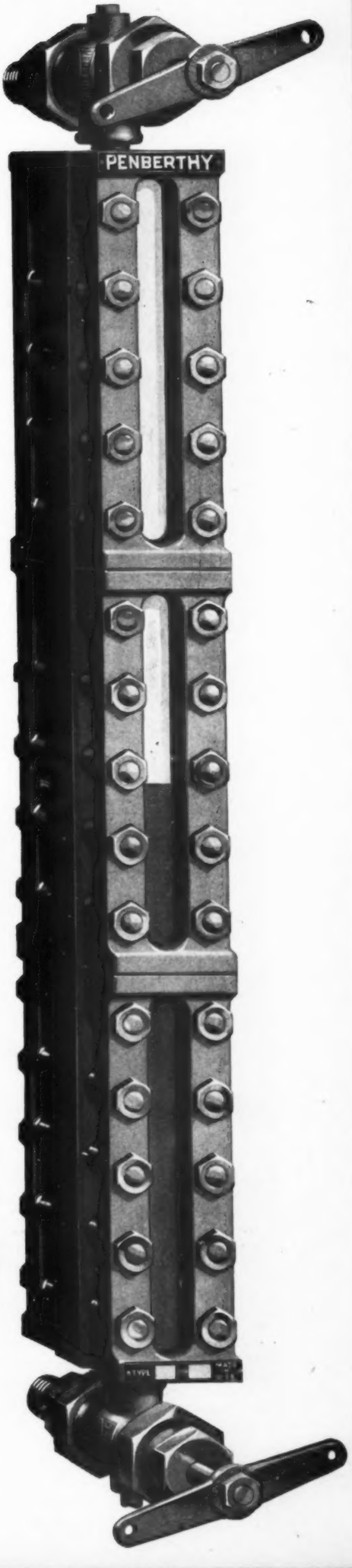
PENBERTHY
Transparent
DROP FORGED STEEL
LIQUID LEVEL GAGES

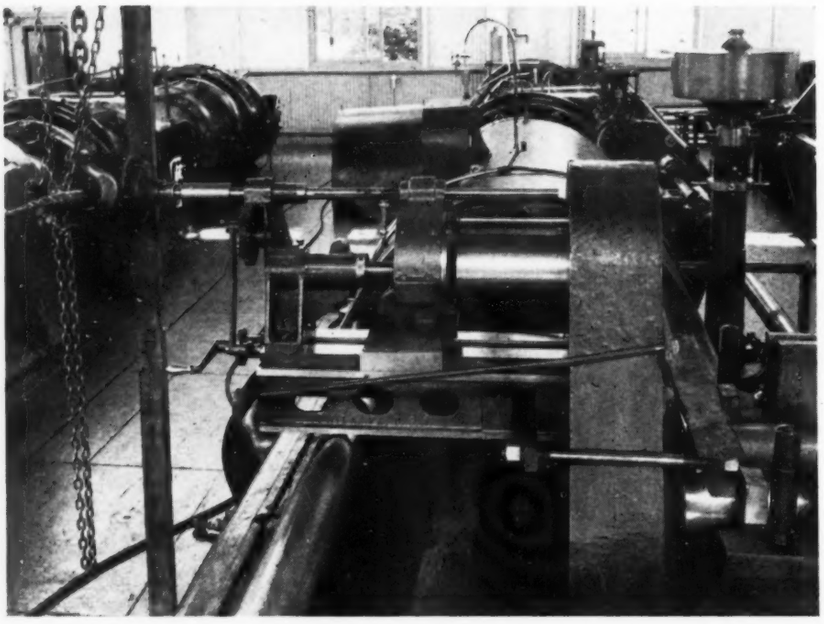
Used to observe color and density of liquids under high pressures, and/or temperatures. Construction is exceptionally rugged... similar to Reflex types.

PENBERTHY INJECTOR CO.

DETROIT, MICHIGAN • **Canadian Plant: Windsor, Ontario**

PENBERTHY PRODUCTS





Truing a crank pin

PETROLEUM ENGINEER Exclusive

by W. E. Nestor
Superintendent Compressor Stations,
Arkansas Louisiana Gas Company

and G. H. McKay
Engineer, Arkansas Natural Gas
Corporation

Machine Shop Plays Important Role in Maintaining Compressor Station Equipment

☆ Scarcity of factory-made parts results in fabrication and reconditioning of numerous repair parts by company machinists

W. E. NESTOR

entered the employ of the Arkansas Natural Gas Company in 1911, previously having been a machinist and master mechanic with various industrial concerns—From 1913 to 1916 he was in charge of construction and operations of the Southwestern Gas and Electric Company stations in the Shreveport, Louisiana, area—In employ of Manufacturers Light and Heat Company, 1916-20, and in 1920 became affiliated with the Reserve Natural Gas Company as superintendent of compressor stations—When in 1928 the various companies now composing the Arkansas Natural Gas Corporation were taken over by the Cities Service Company, he was placed in charge of all compressor stations as superintendent.

WAR-TIME conditions that make it difficult to obtain factory-made parts have caused many companies to fabricate numerous repair parts in their own machine shops, and to resort to ingenious methods to maintain in good repair existing equipment by reconditioning or replacing worn or broken parts.

The company with which the writers are connected has large compressor stations serving defense industries as well as domestic and industrial consumers in the territory in which it operates and is one of the companies doing its part to "keep 'em rolling" and to "keep 'em flying."

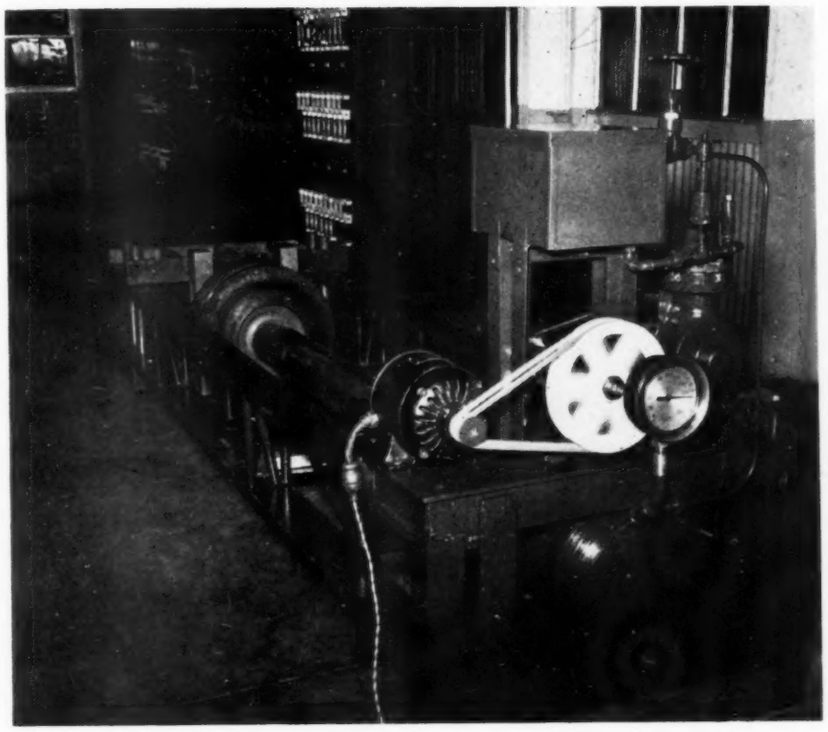
Several of the company compressor stations have been in operation for more than 30 years. In order to maintain these older compressor units in good repair and to keep abreast of the times numerous changes have been made to modernize them to conform as nearly as practicable to present-day types of gas compressors.

Some changes include replacing the old make-and-break ignition system with the more simple and efficient jump spark system, re-designing exhaust valves to obtain better cooling and to reduce stem and seat wear, replacing the old type heavy compressor valves

(Continued on Page 139)

G. H. McKAY

received a bachelor's degree in civil engineering from Mississippi State College, State College, Mississippi, in 1930—After graduation, he was employed by the Arkansas Natural Gas Corporation, and placed in its Junior Engineer Training Course where for two years he received field and office training in the various phases of the company's operations in the gas production, gas transportation, gas compression, gas distribution, oil production, oil transportation, and natural gasoline departments—At the end of the period, he was placed on the general engineering staff of the Arkansas Natural Gas Corporation and has served there for the last 10 years—For the last two years, he has taught natural gas engineering at Centenary College Night School, Shreveport, Louisiana.



Power-driven press for removing pistons from rods

(Continued from Page 136)

with light disk valves[1], substituting bronzed removable bushings for babbitt on crank and wrist pins, and the use of plastic in place of cast-iron for compressor cylinder piston rings.

Economies are effected by the use of electric welding and the metal spray machine to recondition piston rods, cross-head wrist pins, water service, telescopic plungers, exhaust and inlet lever fulcrum pins, and many other parts.

Truing Crank Pins

An interesting repair job recently undertaken at one of the compressor stations was the truing of the crank pins on three 1300-hp. gas engines. These crank pins have been in service for 31 years, and despite the fact that a constant stream of oil lubricates them, the high pressure and constant shock to which they have been subjected over so long a period of time had caused them to wear oblong, making quiet running difficult to maintain and adjustment necessary.

These engines are of the twin-tandem, double-acting type, with 24-in. diameter pistons and 48-in. stroke. They operate at 90 r.p.m. Under full load conditions the crank pins are subjected to a total piston pressure of 120,000 lb. or 820 lb. per sq. in. on the pin. This pressure is alternately applied to each side of the crank pin 90 times per minute just before the crank pin reaches dead center, as it receives the explosion impulse from the 24-in. piston, which in turn transfers this power to the crank pin through the piston rod, crosshead, and connecting rod. It was found that it was at these two points the greatest wear occurred.

In order to correct this condition and return the pins to a true diameter a special crank pin turning machine was purchased from a manufacturer of portable machine tools, which is applicable to any of the company's various side-crank type engines. An accompanying illustration shows the machine in place turning one of these large crank pins, which are 11 in. in diameter by 12 in. long. The machine bed, the end of which is machined to a true right-angle with a spindle, mounted on a bracket on the outer end of the bed, is bolted securely to the machined face of the crank counterweight, and the center in the spindle is centered in the crank pin center, thus bringing the machine in alignment for turning.

The tool holder, which is integral with a ring gear, rotates in a housing, the base of which is dove-tail machined to fit the slide rest on the bed. A small pinion, mounted on a driveshaft and supported by both the traveling head and the outer bracket, meshes with the ring gear to complete the drive.

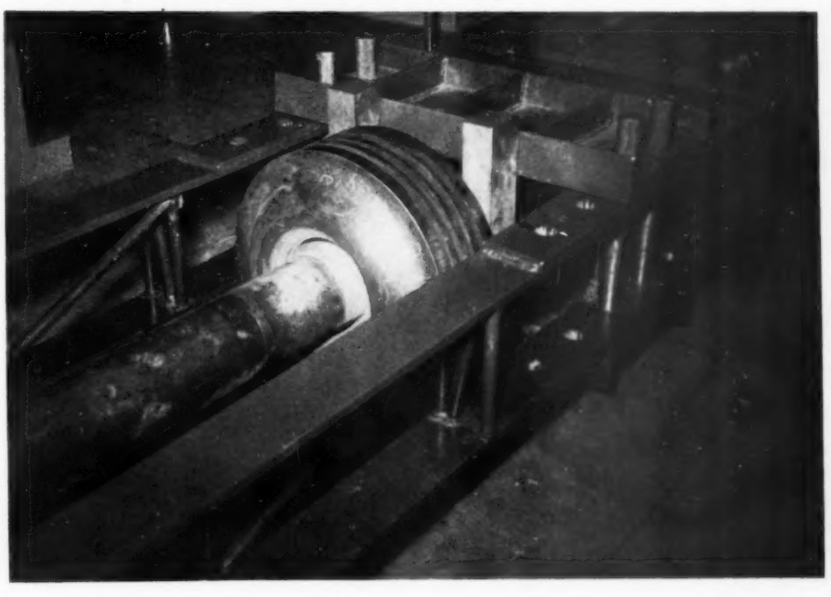
Feed is effected by a lead screw in the base of the machine, attached to a lead nut on the bottom of the traveling head. Gears mounted on the driveshaft and link-connected to an adjustable ratchet drive mounted to the outer end of the lead screw constitutes an automatic feed.

An air drill attached to the driveshaft by taper shank is used to drive the machine. The air drill is supported by the overhead crane.

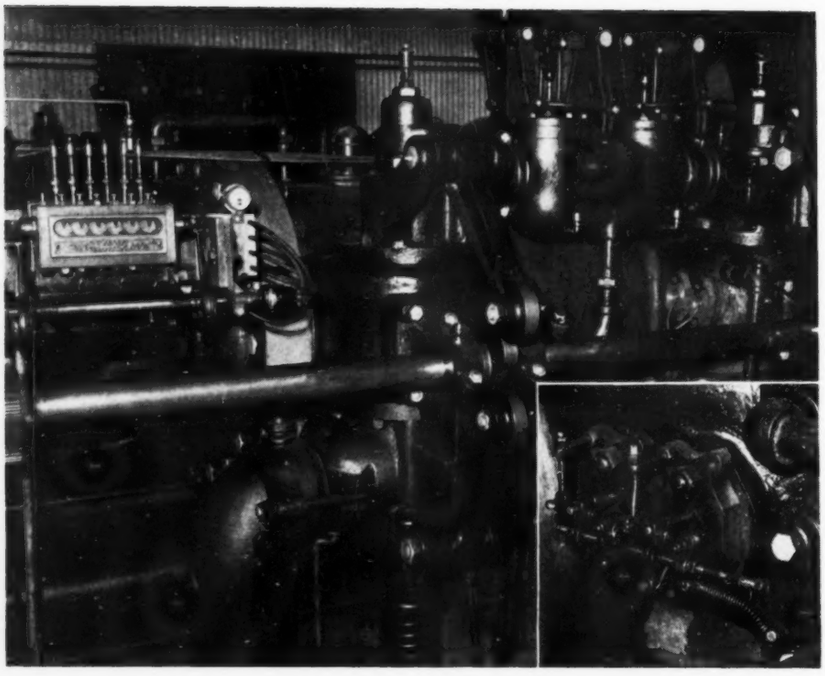
Repairing Heavy Parts

Repairs to major engine parts such as pistons, rods, crankpin bearings, etc., are performed at the company's largest

Closeup of hydraulic press removing a 21½-in. piston from a 21½-in. by 36-in. piston rod



[1]"Modernizing Older-Type Compressor Station Equipment," by W. E. Nestor and G. H. McKay, *The Petroleum Engineer*, March, 1941, p. 66.



Showing adaptation of the jump spark ignition. Inset shows the igniter make-and-break system

station, which is fully equipped to handle these heavy parts, including a 10-ton crane for lifting parts to the machines in the shop.

One of the problems at this plant was removing the pistons from the rods on the larger engines. Formerly the rods were taken to a local machine shop for removal of the pistons. This entailed considerable expense, as these shops were poorly equipped to handle such large pistons and this together with the hauling to and from the shop for dismantling and mounting made repair costs excessive.

To facilitate quick removal of these pistons from the rods, the compressor station engineering department designed a 200-ton fabricated power-driven press especially for this work. Fabrication of the press was all done in the company's shop by the regular machine shop force.

The hydraulic cylinder for the press is a steel forging with 8½-in. bore, honed to a mirror finish and designed to withstand a pressure of 12,000 lb. per sq. in. The ram is of cast-iron with a steel nose and leather cup fluid seat and is returned to normal position by springs attached to the nose piece and by adjustable rods bolted to the front of the press.

The hydraulic pump and motor drive formerly served as a small refrigerating unit and were purchased from a junk dealer for $25. The compressor was converted to a hydraulic pump by inserting a heavy bronze bushing in the cylinder with ½-in. bore, and a ½-in. steel piston was made to replace the 1½-in. piston with which the cylinder was originally equipped. Intake and discharge check valves of the ball and seat type were made in the company's shop.

The motor, ½ hp. and 1750 r.p.m., is of the induction replusion type 220-volts a.c. and drives the pump through a V-belt drive from motor to countershaft and chain and sprocket from countershaft to pump. The speed of the pump is 125 r.p.m. and the ram speed is controlled by the suction valve.

An accompanying illustration shows this machine pressing off a 21½-in. piston from a 21½-in. by 36-in. twin-tandem double-acting engine piston rod. Although these pistons are pressed on at the customary press fit allowance, water corrosion causes the pistons to rust fast to the rod; the pressure required to press the piston off is three to four times that required to press it on.

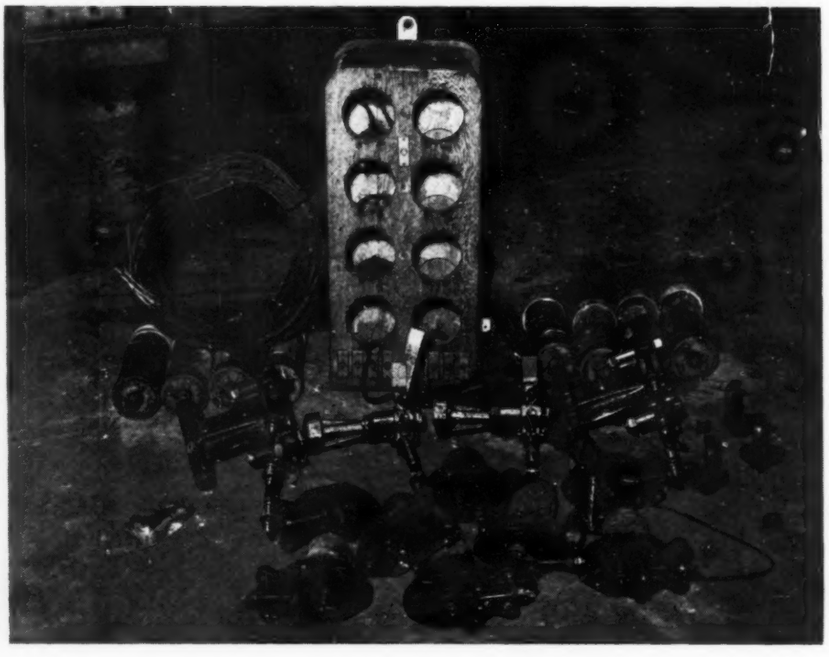
In the illustration the gauge shows 170 tons but the piston did not break loose from the rod until 190-tons pressure was reached.

An illustration shows the adaptation of the jump spark ignition, which is replacing the igniter make-and-break system. War-time economy and extreme simplicity is emphasized in the adaptation of a 4-cylinder automobile timer using only one coil for all eight plugs and driven from the lubricator pump shaft. It is necesary to insulate the wires with a fiber conduit instead of steel. This system of ignition has the advantage of low cost, being only one-seventh the cost of the interrupter system; extreme simplicity in operation, lower maintenance costs, and replacement easily procured.

Another illustration shows the multiplicity of springs, push rods, ignitor coils, bores, wiring, etc., that the automobile timer system has eliminated.

—— ☆ ☆ ☆ ——

Automobile timer system is used in place of the unavailable equipment shown here



reclaiming of used pipe is *fast and economical*

with this AIRCO machine which bevels while it cuts

In salvaging pipe lines for relaying in other areas, many an Airco Pipe Beveling and Cutting Machine is being used to speed the job. One pass of the torches with this oxyacetylene cutting machine and a screwed coupling is removed, the pipe is beveled and made ready for welding in one double-quick operation. Degree of bevel is accurately controlled by a simple hand adjustment of the torch.

Weighing but 43 lbs. complete, this Airco machine can be carried about at will by the operator. An outstanding feature — it needs no electrical power. Either the machine is turned by a hand operated crank and the pipe held stationary or conversely, the machine is held stationary while the pipe is turned — as shown above.

Be sure to avail yourself of the practical assistance of Air Reduction's Applied Engineering Department. It's available for any problems involving the use of the oxyacetylene flame or electric arc.

Air Reduction

General Offices: 60 EAST 42nd ST., NEW YORK, N. Y.

OFFICES IN ALL PRINCIPAL CITIES

IN TEXAS

MAGNOLIA-AIRCO GAS PRODUCTS CO. • HOUSTON

BEAUMONT • WICHITA FALLS • FORT WORTH • DALLAS • EL PASO • SAN ANTONIO

AIRCO WILSON

IDLE CYLINDERS ARE PRODUCTION SLACKERS: *Keep 'em rolling for victory!*

Protection of Natural Gasoline Plants From Air Raids

PETROLEUM ENGINEER Exclusive Feature

☆ Precautions to take beforehand and what to do in event of a raid

by Don Attaway
Safety Engineer, Arkansas Fuel Oil Company

FOR the first time in more than 130 years, the mainland of the United States has been attacked. When an enemy submarine stood off the coast of California and shelled an oil refinery and storage tanks, America had literally been invaded. As a people we have not been fully aroused to the significance of this act. There are three possible reasons for our lethargy. We are, first of all, an inherently peace-loving people. Secondly, we have been the victims of a highly specialized propaganda attack, and finally, we have had no complete casualty lists by which we may know the full extent of our losses.

As members of the petroleum industry, we should be deeply concerned over the fact that this initial attack was against the oil industry. There is no doubt about the tremendous part that oil plays in this war and the enemy has revealed, by this attack and other military moves, that it fully realizes the part petroleum will play in the final outcome.

This is a total war against civilian population and production centers as well as military forces, and we should consider the possibility of air-raid attacks upon our plants and equipment. To do this we should give some thought to what constitutes a vulnerable target and the primary purposes of an air raid. Certainly such an attack would have at least three vital aims. First, it would hope to destroy or cripple production; second, to break down morale, and finally, to create casualties.

The primary requisite of a target is that it have some tactical value. As manufacturers of gasoline our establishments would definitely fall within this qualification. The target should also be within striking distance. As planes are to be used for these raids, the limit is rather wide and difficult to define. We might say that our entire coast line is exposed and as far interior as several hundred miles. Accordingly, we can consider any phase of the petroleum in-

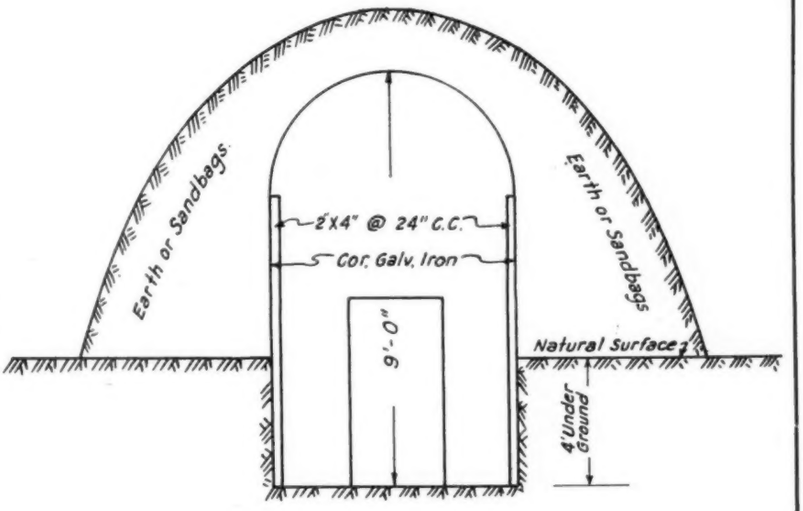
(Continued on Page 145)

DON ATTAWAY

has been safety engineer of the Arkansas Fuel Oil Company since January, 1940, making his headquarters at Shreveport, Louisiana—His first affiliation with the oil industry was with the Dixie Gulf Gas Company in the Waskom district, January, 1928—Joined staff of United Gas Company late in 1929, and accepted position with Arkansas Fuel Oil Company in September, 1930—Has served in various capacities with the latter company.

Sand or earth is first shoveled over the bomb to reduce heat and glare

The snuffer is then dropped over the bomb and sand or earth deposited around any open edges to cut off air



A corrugated iron shelter should provide not less than 5 sq. ft. per person

(Continued from Page 142)

dustry situated in a coastal area as definitely vulnerable. The final requirement of a target is that it be destructible and combustible. Certainly natural gasoline plants are highly inflammable.

Thus we can be certain that our plants meet all the requirements of a valuable target and a succesful raid would produce tremendous loss to our production effort.

Likely Method of Attack

Assuming that we were attacked, let us consider the method and means the enemy would most likely use. High explosives and demolition bombs are likely to be dropped, but these must be delivered from a rather high altitude to prevent damage to the plane dropping the bomb by the subsequent explosion. Direct hits would be limited. At the same time it is reasonable to expect that the attack would come at night. This being the case, the enemy must find certain illumination to use for aiming. The pattern of the German attacks has been a wave of bombers strewing firebombs from a low altitude, which are intended to create the necessary illumination for the demolition attack. Undoubtedly this method is superior as it has been followed rather consistently during the night attacks on England.

Incendiary Bombs

Perhaps a study of the different type incendiary bombs would direct us to the one most likely to be used.

We would certainly expect that the incendiary must be easily ignited. It must also burn with an intensity high enough to ignite any combustible material around it and it must burn long enough to make certain that the ignition is complete. It should be difficult, if not impossible, to extinguish with ordinary means. It should be light in weight so that it could be broadcast more or less wholesale in order to create many small fires at the same time instead of one large flame. Finally, it must be composed of material that is easily procured and cheap to produce.

A review of the most common type of fire-bombs should reveal the one most nearly fitting the requirements just laid down. First, let us study the white phosphorus bomb used by the Japanese against General MacArthur. This type of bomb weighs as much as 30 lb. and an explosive charge in the nose is used to scatter the phosphorus. But phosphorus bombs have limited utility. The material will not ignite spontaneously in cold or wet weather, nor in damp places. Because of its low temperature of igniting, it is suitable only for such material as paper, straw, or leaves. Water extinguishes it quickly. It creates quite a smoke and produces a poisonous action if the phosphorus touches the skin. Evidently it is effective only as a smoke screen or casualty producing agent.

Oil bombs have been used by the Germans, but not with encouraging results. Only about 6 percent of them actually started fires. These bombs range in size from 50 to 500 lb. and the average bomber can only carry a few. They have been extremely difficult to ignite even though the oil is mixed with sodium nitrate or benzene. If dropped from a high altitude, they scatter over too large an area in spots rather than concentrate on one large fire. The oil tends to congeal or "jell" and has been seen to fall in chunks or lumps. Oil bombs have numerous drawbacks.

Thermite bombs have been used by both the Allies and the Axis. They do burn fiercely and ignite easily. Thermite cannot be extinguished; however, they are extremely heavy, weighing 4½ times more than magnesium. Finally, they are costly and expensive to produce.

The most widely used bomb is the magnesium-thermite bomb. It is an ideal incendiary, being light, easily ignited, burning at a very high temperature for as long as 20 minutes, and difficult to extinguish. It is comparatively cheap to produce and rather effective in its work.

This bomb is about 14 in. long, weighs 2.2 lb., has a body made of magnesium alloy, and a tail piece of sheet iron. One large bomber can carry as many as 2000 of these bombs and flying at an altitude of 20,000 ft. at a speed of 200 miles per hour, the plane could scatter incendiaries over an area equal to 800 city blocks. These bombs are released in bundles of 20 or more and fall nose downward, the fall being partially stabilized by the fins. There is no way of aiming or guiding the bomb, and when it strikes the target or earth, a firing pin punctures the detonating cap, which ignites the thermite placed in the hollow magnesium case.

Thermite is a mixture of aluminum and iron oxide, about three-fourths of the composition being iron oxide and the rest granulated aluminum. When burning, this mixture releases free oxygen to supply its combustion and the charge in the bomb will burn about 2 minutes at a temperature of 4500°F. Holes in the side of the bomb near the nose allow the gases generated to escape and molten metal is thrown some 6 ft. about the bomb. The intense heat of the burning thermite ignites the magnesium and this burns for 15 to 20 minutes at a temperature of about 3500°F., but unlike the thermite, the magnesium case requires oxygen from the air.

Undoubtedly this bomb is a perfect incendiary and would most likely be the agent used in an air-raid attack. It meets all the requirements and even adds to its effectiveness by the use of a metal ring around the tail piece that issues a shrieking whistle while falling. These bombs can penetrate 6 in. of wood or ¼ in. of mild steel in a direct hit falling from about 20,000 ft. A

final point about this type bomb is the fact that about one out of every 50 has a small explosive charge concealed in the tail piece.

Defense Against Bombs

It is evident that some preparation must be taken against these bombs and particularly the magnesium-thermite bomb. By the very nature of our business we make a highly visible target. There is little effective camouflage for smoke-stacks, tanks, water vapor, or escaping steam. Therefore our precautions appear to be a reducing of the illumination to a minimum and the shielding of such illumination. Flares at plants can be equipped with relief lines and bypasses for extinguishing the flare. Operations can be conducted with a limited amount of flashlight use and these lights can be shielded. Blackout of a gasoline plant can be carried as far as practicable, but the complete camouflaging of a plant would run into an expense far beyond reason and almost impossible in view of the material shortage.

To combat incendiary attack, each plant should be equipped with the following material. The exact amount of each item will depend entirely upon the number of men on duty at a given time, the size of the plant, its equipment, the number of buildings, and their proximity.

1. Asbestos or fire-proof suits.
2. Sand buckets (2½ to 5 gal. capacity)
3. Long handle shovels
4. Long handle rakes or hoes
5. Gas masks
6. Goggles
7. Heavy or asbestos gloves
8. Fire extinguishers and refills
9. Air-raid shelter
10. Snuffers.

Each plant should be organized with one man in charge of the air-raid protection program. Preferably the plant superintendent should head the program and instruct and train the other personnel in their duties during attack. Each man should know the correct procedure in fighting a fire bomb, combating a gas attack, and operating during attack. The chief operator on shift should be second in charge and the firemen, oilers, and others designated to certain duties.

Definite Routine Essential

A prearranged routine or program will aid in maintaining morale and add effectiveness to extinguishing fires promptly. The Office of Civilian Defense is arranging a warning system and natural gasoline plants in peril will have the benefit of notification. This period of time would allow for the reducing of plant illumination, checking of fire-fighting equipment, laying out first-aid supplies, equipping of men in fire-proof suits, goggles, or gas masks. The plant, of course, must continue in operation.

In case of actual attack, the personnel would station themselves in the air-raid shelter and direct activities from this point. It is suggested that if direct communications are available at the plant, these should be kept open to the main office or headquarters at all times during attack, so that in case of failure, immediate help could be dispatched.

Burning magnesium bombs create intense light and gives the attackers a valuable target; therefore, they should receive immediate attention along the methods outlined below.

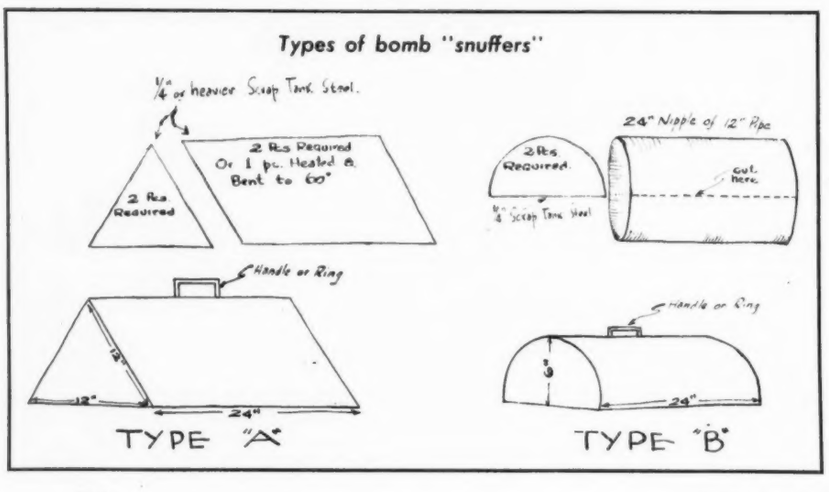
Let us assume a bomb has fallen in an open place such as a road, fence-corner, or firewall. The bomb is actually doing no great harm, but the entire plant is brilliantly lighted. We know the thermite will burn for about two minutes and that the bomb is safe to approach after this time. We can be reasonably certain, too, that if the fire has not caused an explosion by this time, we can safely fight the bomb. Accordingly, one man, designated to that part of the plant, having been provided with fire-proof suit, goggles, and proper gloves, takes the nearest snuffer in one hand and a long handled shovel in the other and approaches the bomb from the up-wind or smoke-free side. The shovel is used to cover the bomb with dirt or sand, preferably dry, to reduce the glare and heat. The snuffer is then dropped over the bomb and stamped heavily into the earth. We know that magnesium cannot burn without air, therefore, the bomb is promptly extinguished.

Let us assume, however, that the bomb has landed near a pump battery and has ignited a puddle of oil. A second man will be required with a fire extinguisher to put out the surrounding fire. In all cases, the surrounding fire must be taken care of before fighting the bomb. To accomplish this, the fire-fighting equipment in natural gasoline plants should be strictly reserved for this purpose and no other. Sand and snuffers and sand buckets can handle the fire bombs, but chemicals are needed for oil and gas fires.

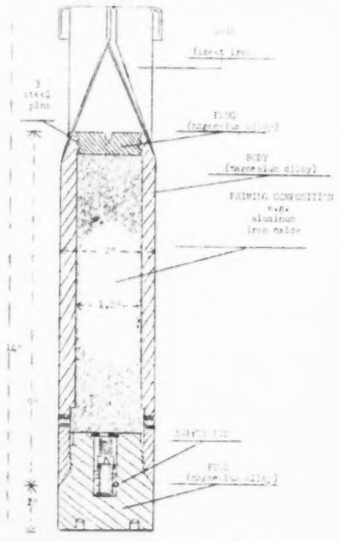
The primary purpose of extinguishing a burning bomb that has not ignited any surrounding material is to eliminate the target value of the fire.

If the bomb falls into a building such as a compressor room, or warehouse, the fighter designated to this place, having been equipped with the fire-proof suit, goggles, and gloves would take the sand bucket, which is ready half-full of dry sand, and a shovel or rake and hoe, to the location of the bomb. A second man would join him with fire extinguisher to handle any surrounding fire. Judgment must be used regarding whether two minutes have been allowed the bomb to cause an explosion. Usually, the thermite will give off a slight yellowish light while burning, and the magnesium creates an intense white light.

In any case, the fire extinguisher should be immediately employed on the surrounding fire and having disposed of any oil, rags, or gas that has been ignited, the fighter can pour half of his sand upon the floor fairly close to the bomb, being sure to leave at least 2 in. of sand in the bottom of his bucket. Then by means of the shovel, the sand from the floor can be scooped over the bomb and the burning case rolled into the sand. Having covered it fairly well, it can be picked up with the shovel and dumped into the bucket. The remaining sand on the floor can be shoveled into the



SPECIFY Tube-Turns FOR EVERY WELDING FITTING NEED!
Available in all sizes in Standard, Extra Heavy, Double Extra Heavy and Special Thicknesses. Write for catalog and data book.
TUBE-TURN
45° ELBOW
90° ELBOW
180° RETURN
TEE
ECCENTRIC REDUCER
CONCENTRIC REDUCER
SADDLE
NIPPLE
LATERAL
CAP
WELDING RING
SLIP-ON FLANGE
WELDING NECK FLANGE
The FIRST WELDING FITTINGS 1ST AND STILL THE BEST
TUBE-TURN



Sketch of German Elektron incendiary bomb

bucket on top of the bomb, then the bucket is lifted by placing the shovel handle through the bail and carried outside to the nearest snuffer, where the bomb and sand are dumped onto the earth, covered again with earth or sand, and smothered by dropping the snuffer over the bomb and pressing it firmly into the earth.

Sand alone will not extinguish the bomb. The burning magnesium case will continue to break through the sand in little puddles or holes and burn in numerous little jets. Exclusion of the air from the magnesium is the only way to extinguish it. Several types of agents have been found to accomplish this. Talcum powder and sand with 10 percent graphite by volume has been found effective. The U. S. Bureau of Mines has found that very hard coal-tar pitch (sometimes called "fuel-pitch") with a softening point of about 300°F. is effective. It should be granulated to pass through a ⅛-in. mesh sieve. When spread over a magnesium fire, it softens and seals the magnesium metal with an airtight blanket.

Probably the most economical and dependable agent for controlling the magnesium bomb is sand. Damp sand will do, although the moisture causes some steam formation. Dry earth also works well. Either sand or earth with the snuffer will extinguish the bomb.

Water may be used in controlling the burning of the magnesium bomb but it will not extinguish it. In fact, a full stream or bucket of water thrown on the burning bomb will cause it to explode, thus spreading the fire over an area where it cannot be handled. A fine spray can be safely played over the burning bomb as it hastens the burning and reduces its time from 15 to 2 minutes. It must be kept in mind that this water spray creates more heat and fire and any inflammable material nearby must be kept wet during the burning period of the bomb.

Any water type fire extinguisher such as the soda-acid may also be used to hasten the burning; however, as much as 6 or 8 gal. of water are required for this burning period of two minutes and the soda-acid cylinder only contains 2½ gal. of water. The foam extinguishers are also good as they produce some 18 or 20 gal. of foam that cools down the surrounding area and hastens the burning of the magnesium.

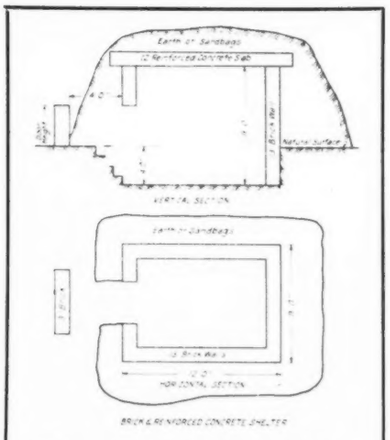
Chemical fire extinguishers are not effective on the magnesium bomb. In fact, the carbon tetrachloride extinguisher creates phosgene gas when sprayed upon the bomb and this is poisonous.

The water spray method and fire extinguishers can be applied to fires within homes, but for gasoline plant purposes, the sand method is faster, more economical, and simpler. Regulation fire-fighting equipment at plants should be strictly set aside for handling adjacent fires.

Perhaps some thought should be given to the possibility of fire bombs penetrating gasoline storage tanks. Tests have shown that if the time between impact and penetration of the oil is fast enough to prevent ignition of the vapors above the liquid, the bomb will burn out under the gasoline. Of course, the amount of gasoline in the tank must be enough to submerge the bomb a foot or more. Bombs falling in water will react in a similar manner. They do not extinguish themselves, but rather burn out under water. The generation of gases are enough to keep the water from sealing the sides and ample oxygen is obtained from the decomposition of the steam and water. In relatively deep water, cases have been known where the thermite core burned away but the magnesium case was cooled sufficiently to be left intact.

In dealing with the fire bomb, the essentials of fire must be kept in mind. A fire is like a triangle in construction. One side is formed by fuel, a second side is formed by air (or oxygen), and a third side formed by heat (or ignition). When these three factors are brought together in the proper ratio, a fire is inevitable. By the same token, a fire can be extinguished by the removal of any one of the three sides of the triangle. The technique may be simple. If the children of England can handle fire bombs, it is quite certain that the natural gasoline plant operators of America can do the same.

Possibly the one bright spot in the



This brick and reinforced concrete shelter will accommodate 12 persons

likelihood of air raids is the fact that the majority of our gasoline plants are not in congested areas, and will not come in for the amount of exposure that cities and densely populated areas will face. Many plants are well isolated and surrounded by dense woods that form a natural sort of protection or disguise.

Other Factors

In any case, preparations should be made for any possibility and a thorough knowledge of the fire bomb is essential. The other factors required are nothing more than the average American's good common sense and courage. These are:

1. Keep cool. Above all, don't lose your head. Keep order and remember that the chance of your being hit is small.

2. Stay under cover during attack. Don't expose yourself needlessly during attack. If engaged in fighting a fire bomb and high explosives begin falling lie down flat. You will feel the blast less and escape splinters and fragments.

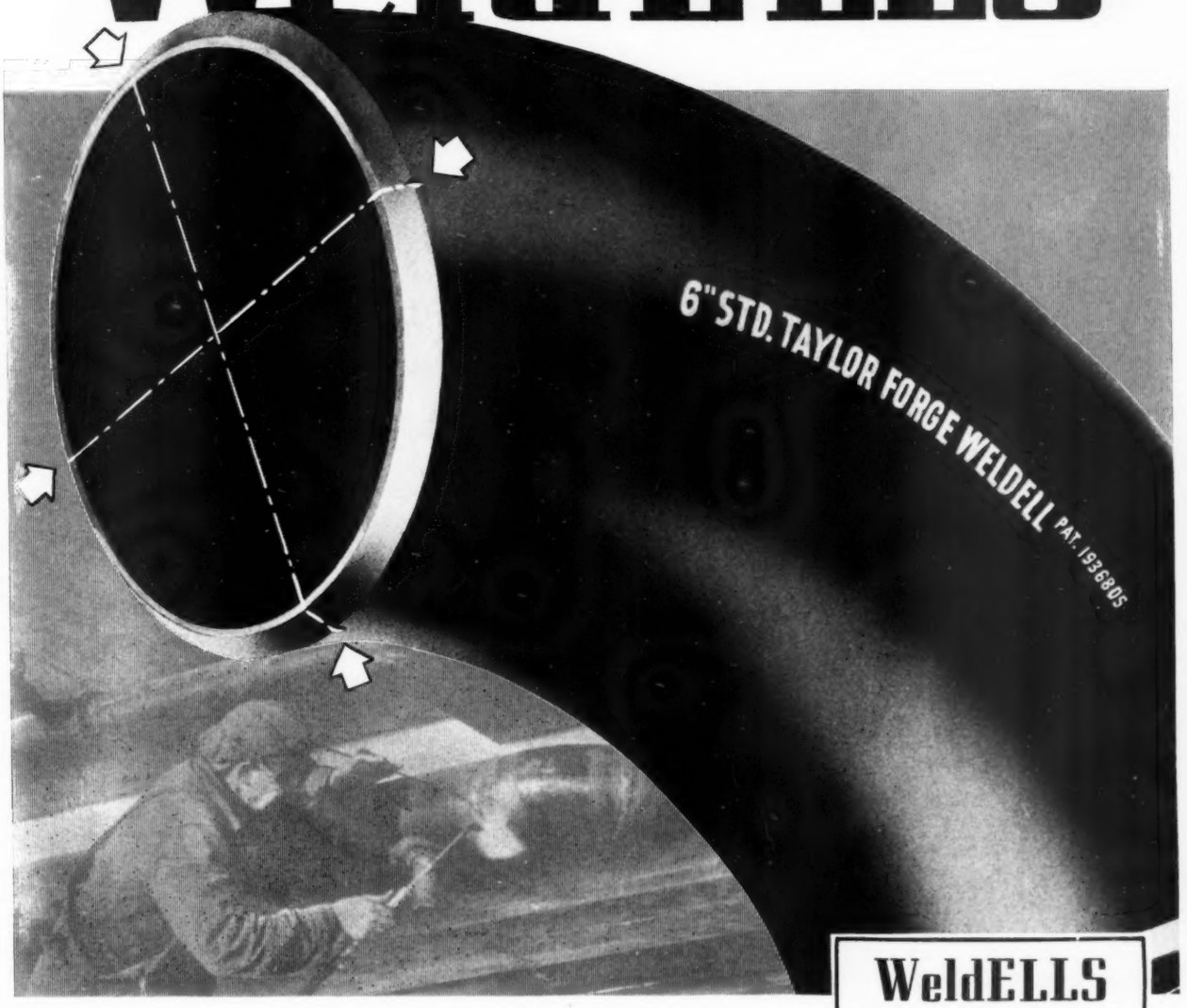
3. Don't shut down equipment. Shutting down equipment is usually the worst possible action. If boilers are cut out, reflux pumps stop, stills pop, surge tanks overflow. If circulation is stopped through direct-fired preheaters, tubes may rupture. Keep your head and follow instructions only regarding what units may be safely shut down.

4. Don't show light. If planes come over, put out all lights. The light that cannot be seen will never guide an enemy airman.

5. Life and limb come first. Tend to the wounded and injured first. Don't take unnecessary chances. Equipment can be repaired or replaced, a human life cannot.

—— ☆ ☆ ☆ ——

WeldELLS



THEY SPEAK HIS LANGUAGE

—*these precision quarter-marks*

Just ask the man who welds them, if you question the importance of these precision quarter-marks that are found only on WeldELLS and other Taylor Forge Welding Fittings.

He'll tell you how much time and trouble these reference points save in figuring center lines, angles and offsets; how much easier they make it to keep piping lined up in the proper plane. Fact is, this exclusive feature would be reason enough to insist on WeldELLS even if they didn't have the many other improving features listed opposite.

But quarter-marks are only one extra value of the fittings that have *everything* . . . for the man who specifies, welds, or pays the bill!

WeldELLS
have *everything*—

No other fittings for pipe welding combine these features which in addition to quarter-markings include:

▶ **Seamless**—Greater strength and uniformity.

▶ **Tangents**—Keep weld away from zone of highest stress—simplify lining up.

▶ **Selective reinforcement**—provides uniform strength.

▶ **Permanent and complete identification marking**—saves time and eliminates errors in shop and field.

▶ **Wall thickness never less than specification minimum**—assures full strength and long life.

▶ **Machine tool beveled ends**—provide best welding surface and accurate bevel and land.

▶ **The most complete line of Welding Fittings and Forged Steel Flanges in the World**—insures complete service and undivided responsibility.

TAYLOR FORGE & PIPE WORKS, General Offices & Works: Chicago, P. O. Box 485
New York Office: 50 Church Street • Philadelphia Office: Broad Street Station Bldg.

Conversion of Gasoline Plants To Increase *Iso*butane Extraction

☆ Suggested methods for analyzing existing individual plants — Maximum justifiable extraction percentage determined by cost

by W. L. Rifenberick
Vice-President, Industrial Engineers, Inc.

AMONG the most discussed subjects today relating to gasoline plant operation is that of the best method of converting existing gasoline plants to higher *iso*butane and propane extractions. The conversion must be accomplished with a minimum of new materials, particularly new compressors, which are on an allocation basis—and not too many are allocated to this industry. Engines are needed for the direct prosecution of the war.

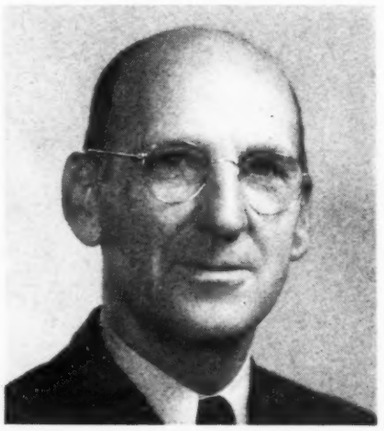
A general rule cannot be laid down for all plants to follow to increase the extraction of the lighter hydrocarbons. It depends entirely on the plant and the surplus equipment and capacity available. There are many possibilities and methods that may be employed to increase extraction. Among these methods are:

1. Increased oil circulation.
2. Reduced oil temperature.
3. Increased absorption pressure.

Increased Oil Circulation

The effect of oil circulation on extraction is well known. In many plants the desired results can be obtained by increased oil circulation to remove the lighter hydrocabons from the gas. This is possible only in plants having excess capacity in absorbers, coolers, exchangers, stills, cooling tower, etc.

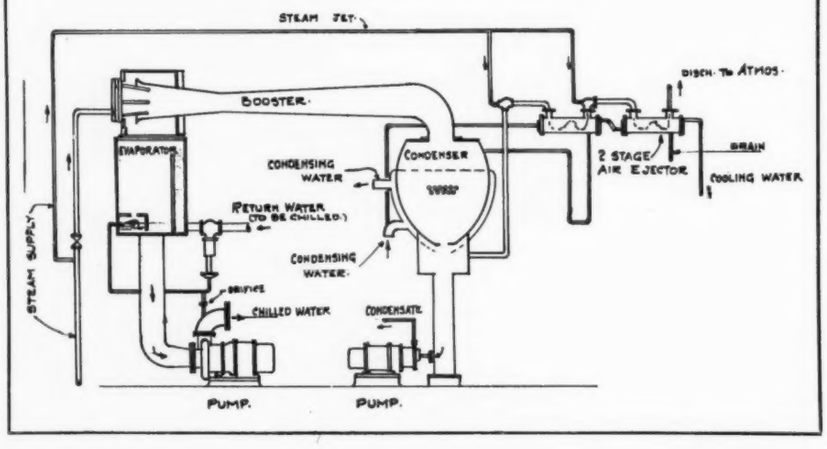
Thinking in terms of *iso*butane, only about 90 percent extraction at present prices of the product can be justified. In many cases 95 percent *iso* extraction is being made. The additional 5 percent will in many instances cost more than the value of the product. Here again the total volume possible to extract will largely decide the economies of the extraction. It is necessary to determine the cost to obtain various percentages of *iso*butane to decide the maximum justifiable extraction. If at some future time essentially 100 percent *iso*butane extraction must be obtained it will be necessary for the government to subsidize the additional cost or the gasoline plant must produce the increased quantity at a loss. An increase in price of the *iso*butane will permit a greater extraction. If the price would justify the investment and a market was available for a number of years, the gasoline manufacturers would welcome the chance to extract essentially 100 percent of the *iso*butane.



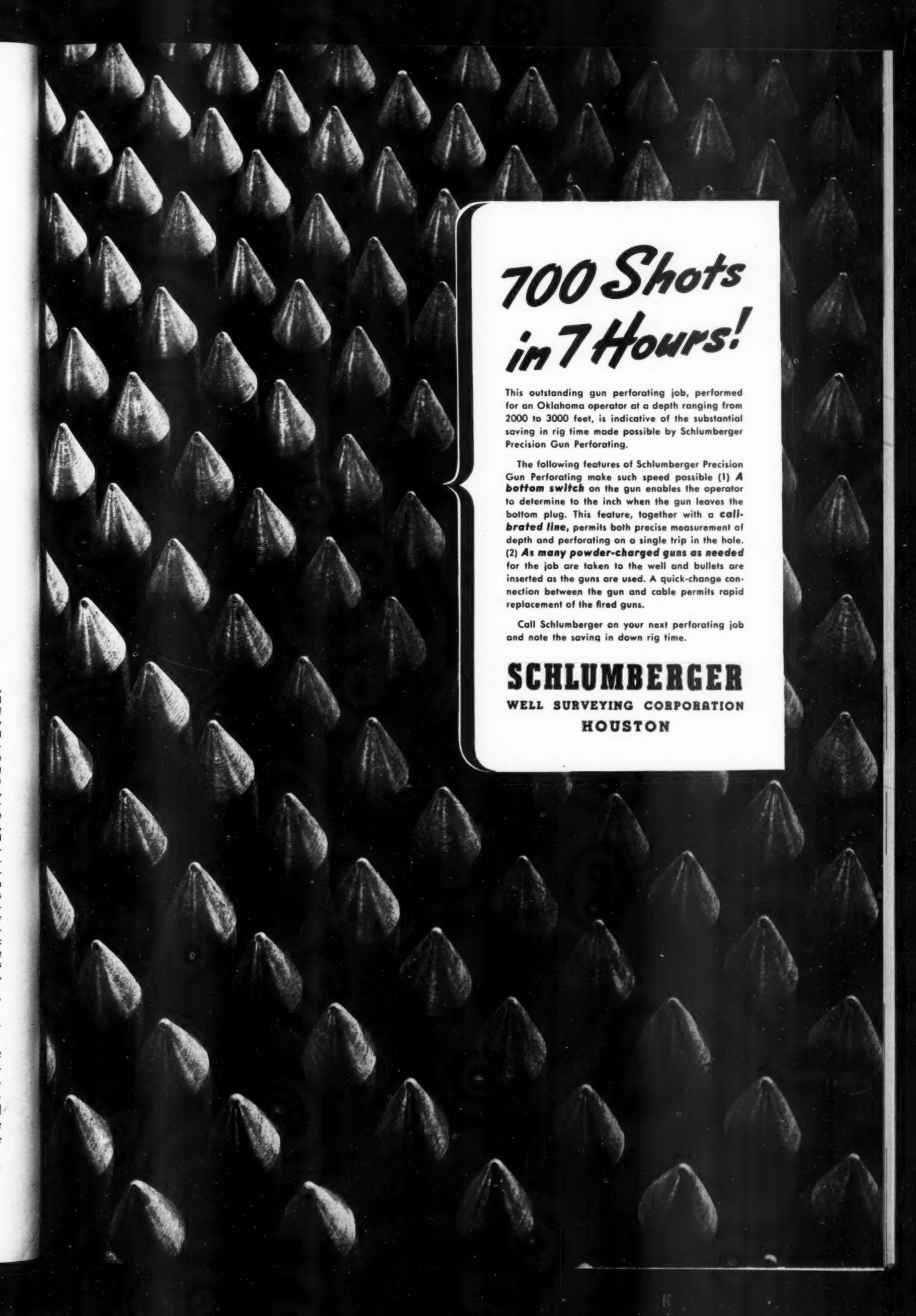
W. L. RIFENBERICK

graduated from Stanford University in 1917, where he was elected to Sigma Xi for original work on bearings—He spent one and one-half years in the Army, transferring from infantry to Air Corps, then on detached duty to National Advisory Committee for Aeronautics at Washington, D. C., and Langley Field, Virginia—He received a degree in mechanical engineering from Stanford in 1919—Was design draftsman for Federal Telegraph Company, Palo Alto, California, later being engaged as design engineer for Moreland Truck Company—Entered the oil business in 1919 with Shell Oil Company, Inc., as gas engineer—In 1925 he organized and was president of Mutual Gasoline Company, Signal Hill, California—Became sales engineer for Southwestern Engineering Corporation in 1926 and was later sent to Venezuela to study and develop a method to treat gas produced on Lake Maracaibo—In 1929, organized gasoline department of Foster Wheeler Corporation—When Consolidated Steel Corporation, Los Angeles, was appointed Pacific Coast agent for Foster Wheeler in 1932, he became sales engineer for the former—Has been vice-president, Industrial Engineers, Inc., Los Angeles, since 1935.

Fig. 1. Flow sheet of steam jet cooler



In many of the present-day gasoline plants the necessary increase in gasoline extraction can be made by additional lean oil circulation. Many consider this the most inexpensive method of obtaining the desired results. There may be minor "bottlenecks" when the



700 Shots in 7 Hours!

This outstanding gun perforating job, performed for an Oklahoma operator at a depth ranging from 2000 to 3000 feet, is indicative of the substantial saving in rig time made possible by Schlumberger Precision Gun Perforating.

The following features of Schlumberger Precision Gun Perforating make such speed possible (1) ***A bottom switch*** on the gun enables the operator to determine to the inch when the gun leaves the bottom plug. This feature, together with a ***calibrated line***, permits both precise measurement of depth and perforating on a single trip in the hole. (2) ***As many powder-charged guns as needed*** for the job are taken to the well and bullets are inserted as the guns are used. A quick-change connection between the gun and cable permits rapid replacement of the fired guns.

Call Schlumberger on your next perforating job and note the saving in down rig time.

SCHLUMBERGER

WELL SURVEYING CORPORATION

HOUSTON

oil rate is increased, among which is the added quantity of fixed gases. This will be discussed later.

Reduced Oil Temperature

A plant operating near its rated oil circulation can resort to reduced oil temperatures as one of the best means of increasing extraction. This may be accomplished in several ways. It may be accomplished by reducing the load on the cooling tower. The plant should be examined with a view to reducing the steam consumption in the still for agitation. A reduction in this direction will beneficially affect the cooling tower load with a lower cooling water temperature to the oil coolers.

An example of the possibilities along this line can be given from operating results on two stills of the same diameter and design. One is a unit having seven stripping and seven fractionating trays. It operates at 35 lb. per sq. in. gauge pressure and requires 0.25-lb. steam per gal. of lean oil. The bottom temperature is about 330°F. Another unit has ten stripping and ten fractionating trays. It operates at 55 lb. and a bottom temperature of 345°F. It requires only 0.124 lb. steam per gal. of lean oil. Placing the two units on the same basis of bottom temperature and operating pressure, the seven tray still would require 0.30 lb. of steam at 55 lb. for a bottom temperature of 345°F. This comparison is not strictly correct because the seven stripping tray tower seemingly strips the lean oil to a lower vapor pressure than the one having ten trays. The comparison is probably more nearly 0.124 lb. for the ten-tray tower and 0.20 for the seven-tray tower. Each still is operating at approximately the same rate of throughput. In a plant circulating 500,000 gal. of lean oil per day the decreased load on the cooling tower from reduced steam condensation would amount to 1,535,000 to 3,550,000 B.t.u. per hr. based on the difference in steam rates for the seven and ten stripping trays. This is in addition to any other reduction in heat load on the condensers resulting from decreased reflux accompanying the lower steam rate. The advisability of adding more trays to the still on a revamping of the still in general to reduce the heat load on the condensers is well worth considering.

Another means of reducing the cooling tower load is to examine the heat exchangers. If the lean oil is not cooled to within 20 or 30°F. of the fat oil entering, the condition is worthy of some study. First, determine that the exchangers are well cleaned either mechanically or chemically. Chemical cleaning of exchangers is one of the best ways of assuring a good job. If, after

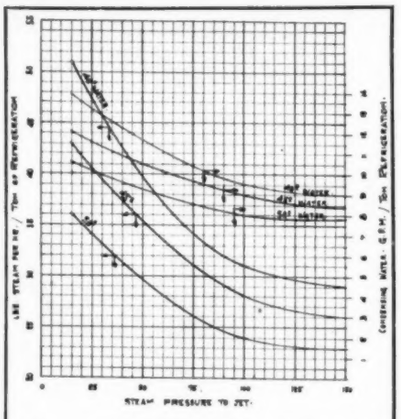


Fig. 2. Approximate steam and condensing water required per ton of vacuum refrigeration. Curves for 40, 45, and 50°F. refrigerated water. Cooling water to condenser, 80°F.

cleaning, the approach on the cold end is in excess of 30°F., the addition of more exchangers may prove advisable. For example, assume the approach is 50°F. on the cold end of the exchangers with the oil circulation of 500,000 gal. of lean oil per day, a reduction to 25°F. with additional exchange will result in a decrease of approximately 1,800,000 B.t.u. per hr. on the coolers and cooling tower.

If reduction in agitation steam and/or lean oil temperature to the coolers do not appear to give enough decrease in cooling water temperature, the cooling tower installation should be investigated. Do not try to convert a natural-draft cooling tower to a forced- or induced-draft type to lower the temperature. It will not be successful. A natural-draft tower is built for cross flow of air and air cannot be economically blown across a natural-draft tower. Likewise, air cannot be blown upward in a natural-draft tower. The resistance through the decking is too great. It is better to investigate the addition of another tower or a forced-draft unit to cool the water from the natural-draft tower. In some localities where there are periodic low wind velocities resulting in high water temperatures, it is believed the situation can be remedied by the use of a forced-draft tower to cool the water from the natural-draft tower nearer the wet bulb temperature. The fans need not be operated when the water from the natural-draft tower is at a satisfactory approach to the wet bulb.

One way of materially reducing the cooling tower load in a plant with a number of compressors is to cool the jacket water in radiators. Engine jacket water should be circulated at approximately 1 gal. per hp., which gives a low temperature rise through the jackets. This permits a relatively high water temperature with less engine wear and strain than with a low water temperature and 20°F. rise. Temperatures of 150 to 180°F. are very satisfactory for large engines. This makes cooling with radiators very economical even though the air temperature is as high as 110°F. in the summertime. One installation in an electric generating plant employing radiator-type water and oil coolers, has a capacity of 3750 hp. and is designed for 110°F. air temperature. The oil coolers are directly under the main radiators for the jacket water. The proper number of fans is operated to keep the water and oil at the desired temperatures. Hand-operated shutters are on the oil coolers to control the oil temperature independent of the water.

Refrigeration to Lower Oil Temperatures

If the oil temperature cannot be reduced sufficiently by eliminating loads, then some form of refrigeration must be resorted to. It must also be borne in mind that whereas the load would be reduced as already suggested, an increase in products extracted would increase the condenser load.

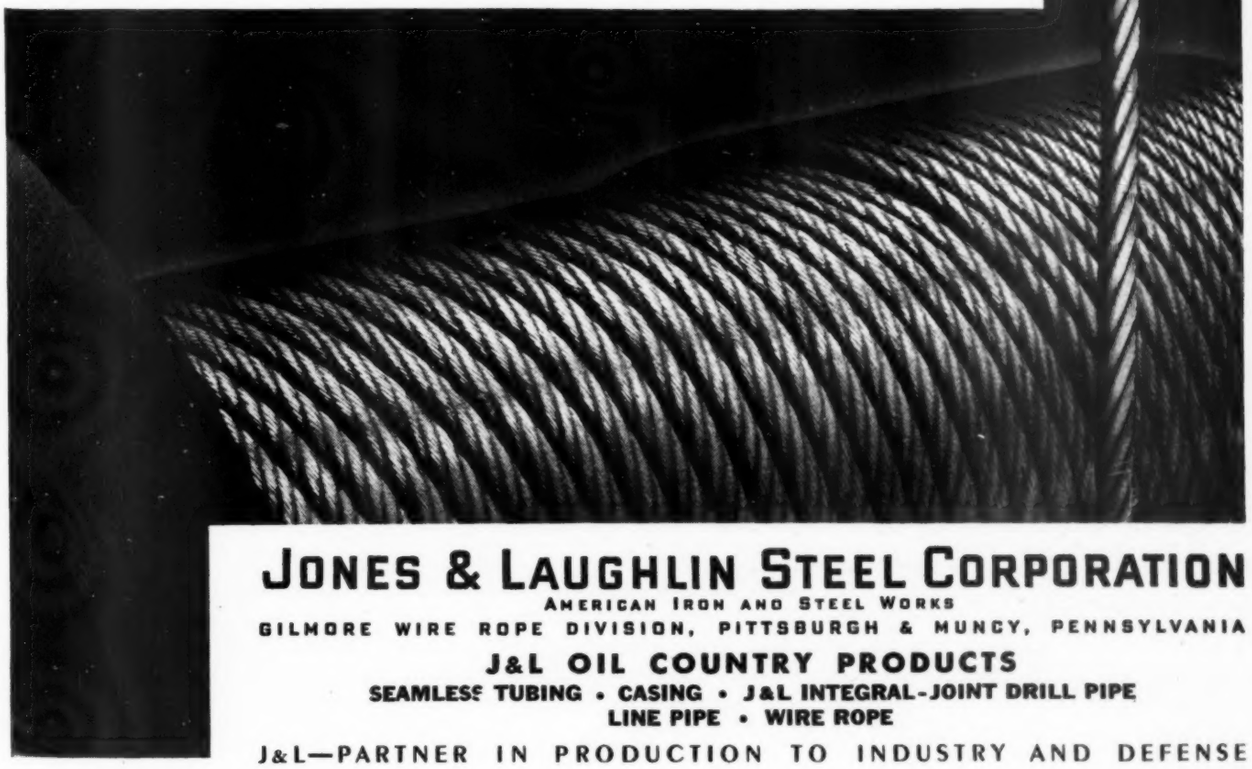
If compressors are available mechanical refrigeration will undoubtedly prove the best method. This process consists of compressing propane or butane vapors or a mixture of the two, condensing them and expanding the condensate through coolers to cool lean oil, gas, or gasoline, etc. Many plants are using this method.

Another process is available that merits a great deal of consideration and study. This is particularly true in plants having excess boiler capacity or a large quantity of exhaust steam available. It is the so-called "vacuum refrigeration." Fig. 1 is a flow sheet of such a unit. It consists essentially of a water tank, thermo compressors, a condenser, and air jets in addition to the pumps. The tank contains the water being refrigerated and the thermo compressor is used to produce a vacuum in the tank. The actuating steam can be as low as 1 lb. gauge. The higher the steam pressure the less steam required. The vacuum corresponding to, say, the vapor pressure of water at 45 or 50°F., causes the water in the tank to boil until the temperature of the water corresponds to the vacuum. As water is constantly entering and also leaving the tank, the water is always boiling. The thermo compressor raises the water vapor or steam boiled off to the pressure required for condensation with cooling water at 80 or 90°F. It is impossible to condense the steam boiled from the water with

J&L STEEL

J & L Permaset **PRE-FORMED** WIRE ROPE

—made of J & L Controlled Quality Steel—pre-formed by men of skill and experience—has rugged strength—greater flexibility—gives extra service per dollar—helps step-up production of oil for industry and defense.



JONES & LAUGHLIN STEEL CORPORATION

AMERICAN IRON AND STEEL WORKS

GILMORE WIRE ROPE DIVISION, PITTSBURGH & MUNCY, PENNSYLVANIA

J&L OIL COUNTRY PRODUCTS

SEAMLESS TUBING • CASING • J&L INTEGRAL-JOINT DRILL PIPE

LINE PIPE • WIRE ROPE

J&L—PARTNER IN PRODUCTION TO INDUSTRY AND DEFENSE

normal cooling water until the pressure has been raised through the thermo compressor. Usually a 2-stage air jet is used on the outlet of the condenser to raise the air from the boiled water and steam to atmospheric pressure. A barometric condenser may be used in place of a surface condenser as shown in the diagram but the condensate is not available for boiler feed water with that type of condenser. In large installations a number of thermo compressors are used in parallel on the water tank.

The condenser load on a vacuum refrigeration unit must condense, not only the actuating steam to operate the thermo compressor (or booster as it is sometimes called), but in addition the steam evaporated from the chilled water.

Fig. 2 shows the effect of steam pressure and the quantity required to produce a ton of refrigeration (a ton of refrigeration is 12,000 B.t.u. per hr.). Likewise the quantity of cooling water is given. The curves indicate what may be called high averages. Equipment is available today that will give a ton of refrigeration with 25 percent less steam, but the curves are very safe for estimating the steam and water required.

In some cases low-pressure steam is used insofar as it is available, supplemented with live steam used in other jets to produce the refrigeration required.

The following figures may be used to estimate the cost of the equipment in a vacuum refrigeration unit. These consist of the price of tank, surface condenser, booster, air jets, pumps, and interconnecting piping, but not cooling tower or cooling tower pumps. Neither does it include steam and water piping to or from the unit.

300 ton:
$56.00 per ton of refrigeration
500 ton:
$53.00 per ton of refrigeration
700 ton:
$48.00 per ton of refrigeration.

The water refrigerated in the unit is circulated through exchangers to remove the heat from the oil, wet gas, etc.

The percentage extraction, of any hydrocarbon, from the wet gas is directly proportional to the vapor pressure of that product at fat oil temperature. In the case of *iso*butane, reducing the temperature from 100 to 70°F., should increase the extraction in the ratio of 74 to 45 or 39 percent; 74 and 45 are the vapor pressure of *iso*butane at 100 and 70°F., respectively. This is a material increase in extraction. Fewer fixed gases are absorbed as the temperature of the oil and gas is reduced. This is very important.

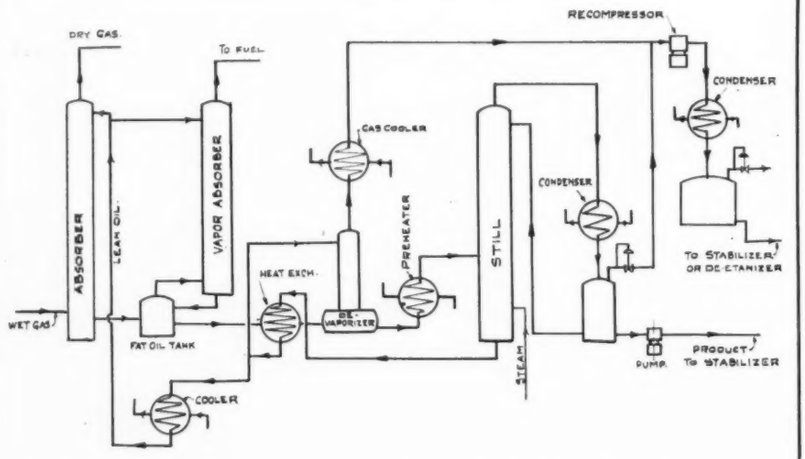


Fig. 3. Flow sheet showing recompression method of handling plant vapors except fat oil tank vapors

Any increase in *iso*butane extraction costs energy in one form or another. If increased oil circulation is used, costs are incurred in the form of more pumping load, heating, cooling, etc. If it is accomplished by means of reduced oil temperatures, the pumping load may remain constant, but the extra work will be in the form of additional refrigeration.

Cooling Wet Gas

In the high-pressure absorption plant, it is not enough to cool the lean oil alone as in many cases the weight of wet gas processed may exceed the weight of lean oil circulated. In practically every case it is vitally necessary to cool the wet gas just as cold as the lean oil.

Even in the case of low-pressure absorption, it is very necessary to cool the wet gas before entering the absorber.

In some cases the mean temperature in the absorber can be reduced amply by taking the oil from the absorber a few trays from the top, cooling it, and pumping it back. If it is impossible to get into the absorber to install a take-off for the partly enriched fat oil, the same result may be accomplished by building a short absorber having 4 to 6 trays. The lean oil then enters in contact with the gas from the main absorber. The semi-fat oil is forced over the top of the main absorber with a pump. This provides a relatively inexpensive way of removing the heat of absorption of the lighter fractions.

Presaturation of the lean oil reduces the fat oil temperature at the absorber outlet, but likewise reduces the quantity of the pre-saturant absorbed from the gas. If surplus propane is added to the lean oil, the quantity of propane extracted from the dry gas is reduced. If maximum propane extraction is desired, use of ethane as a pre-saturant will give beneficial results. Pre-saturating with the desired product to be removed from the gas is not conducive to maximum recovery of that particular constituent.

Increased Absorber Pressure

In a few low-pressure plants, the absorbers can be operated at a higher pressure. This may or may not be sufficient to obtain the necessary increased extraction. Often bottlenecks may have to be removed to permit the desired results. For example, if the single-stage compressors are operating at capacity in volume and compression ratio, it may be possible to two-stage the compressors to reduce the horsepower per M. cu. ft. of gas. The lower the compression ratio the higher the volumetric efficiency of the units. Less gas is in the cylinder at the end of the compression stroke to re-expand and reduce the fresh gas taken in on the suction stroke. The net result of changing a high-compression ratio single-stage compression to two-stage with gas intercooling is to compress the same quantity of gas with less horsepower.

If 35-lb. absorption can be increased to 50-lb. the ratio of increased extraction of products is in the ratio of the absolute pressures or 65 divided by 50. This results in 30 percent increased extraction disregarding increased absorber temperature due to additional hydrocarbons absorbed.

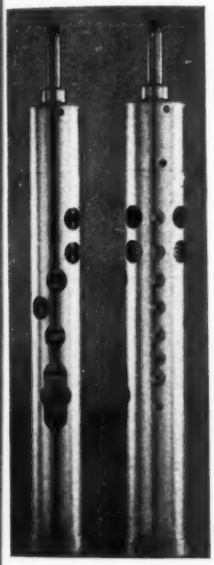
The methods discussed of increasing extraction of *iso*butane are a few that should be investigated. There are many

E.L.I. EQUIPMENT IN WORLD-WIDE SERVICE

Within ONE organization E.L.I. offers complete facilities for Research, Design and Manufacture of precision instruments and equipment, which include:

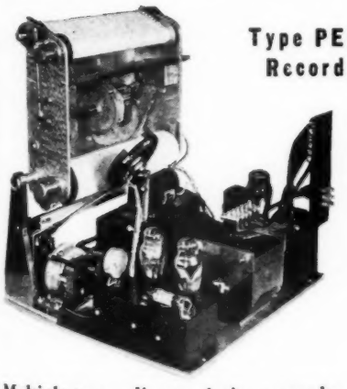
Type RO-5
Recording Oscillograph

Photographically Recording Oscillographs, 8 to 24 elements, electromagnetically damped, moving coil, mirror type galvanometer. Instrument has a removable light-proof magazine for daylight operation, especially designed for portable seismograph work.



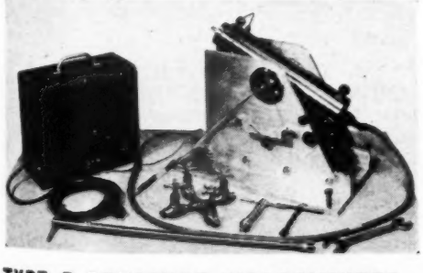
Tube Clock

Recording element for use with E.L.I.-built Humble Type Subsurface Pressure Gauge. Twenty-four hour per revolution, sixty-hour movement. Other types with one- and two-hour (per revolution) movements.



Type PER-1
Recorder

Multiple-trace, direct-printing recorder, with a frequency of printing above that of previous multiple-print recorders.



TYPE D PRESSURE VISCOSIMETER

Humble-Design — with this instrument the viscosities of small subsurface oil samples are measured under actual reservoir conditions of temperature and pressure in connection with E.L.I. Subsurface Samples.

Lengthen the life of your
E. L. I. INSTRUMENTS
By keeping them in perfect repair

Your E.L.I. equipment is essential for greater accuracy and efficiency in the exploration, production and conservation of petroleum for the war effort. Our 24-hour service assures prompt repair and recondition of your E.L.I. instruments with minimum loss of service and maximum life for the equipment.

PRECISION MANUFACTURE -by E.L.I.

Throughout the past eleven years E.L.I. has contributed many instruments and developed services vital to the Petroleum Industry. Equipment that is in World-Wide use. Today, although we are operating on a 24-hour schedule supplying vital precision-built equipment to leading aircraft manufacturers . . . helping the United Nations to finish the job! . . . E.L.I. Research and Design goes on. That when conditions permit, we will be able to supply you precision instruments and equipment to locate and increase the production of oil, decreasing costs through conservation.

Checking contour. Small dial registers in thousandths of an inch.

Inspecting for shipment E.L.I. units, some of whose dimensions must be held within one-fourth of one thousandth of an inch of absolute accuracy.

One of the many E.L.I. machine tools for precision manufacture.

Engineering Laboratories, Inc.

CONSULTING ENGINEERS AND MANUFACTURERS

624 East Fourth Street
TULSA, OKLAHOMA U. S. A.

others that may be peculiar to the plant in question. The effect of the contemplated change should be studied in relation to the rest of the operations and how it will effect the entire plant. Many times a change may produce a desired result in one piece of apparatus, but upset some other part of the plant, which may nullify the benefits. Above all, survey the plant as a whole and determine the overall result. What good does it do to increase the extraction from the wet gas if it results in such a large quantity of fixed gas that the rest of the plant cannot recover the desirable fractions from these gases? The net result may be no more product in the tanks. It may be removed from the wet gas but lost in the rest of the plant, or such a large recycle built up that it is eventually lost through reduced oil circulation per unit volume of gas treated.

Handling Increased Quantity

After the additional extraction has been made it is then necessary to handle it in the most efficient manner. In other words, the main absorbers are what might be called concentrators of the desired hydrocarbons together with many undesirable ones. There are several ways of handling these vapors. First of all the method should not build-up a large recycle in the plant. Otherwise too much lean oil circulation is necessary merely to hold something already captured.

Consider a high-pressure absorption plant. The following method is expected to give about as satisfactory results as any considered.

Fig. 3 is a very simplified flow sheet showing the method to be discussed. The fat oil is vented at a pressure between 100 and 250 lb. depending upon the plant and operation. The vapors from the fat oil can be reabsorbed at fat oil tank pressure in an auxiliary absorber placed next to and above the fat oil tank. Lean oil can be circulated over this absorber, which need have only a few trays. The fat oil can flow back into the fat oil tank, and the unabsorbed vapors are discharged to the fuel system.

Another method to dispose of the fat oil tank vapors is to recompress to main absorber pressure and introduce into the main gas stream. The fat oil tank pressure should be maintained as high as possible and still be able to compress and condense all other plant vapors.

The vapors from the devaporizers between exchangers and preheater must go through a few trays in a tower to clean up the color and end-point of the product condensed later. They must also be cooled before compression. Compress the vapors to whatever pressure necessary to reduce the losses in the tail gases to a negligible quantity.

The condensate from these various sources should be fed to the gasoline stabilizer. If the stabilizer is not built for sufficiently high pressure to handle the condensate it will be necessary either to de-ethanize the product in a small stablizer or flash it. The flash vapor can be put back into the reabsorber. This increases the recycle load, however, and is not recommended.

In Fig. 4 the method of handling the plant vapors is varied somewhat. A major part of the work involves absorption but without recycle. The fat oil and devaporizer vapors go to a reabsorber. The fat oil from this absorber has its own set of exchangers. It then enters the main fat oil stream just ahead of the preheater. A large quantity of fixed gasses have been eliminated before reaching this point.

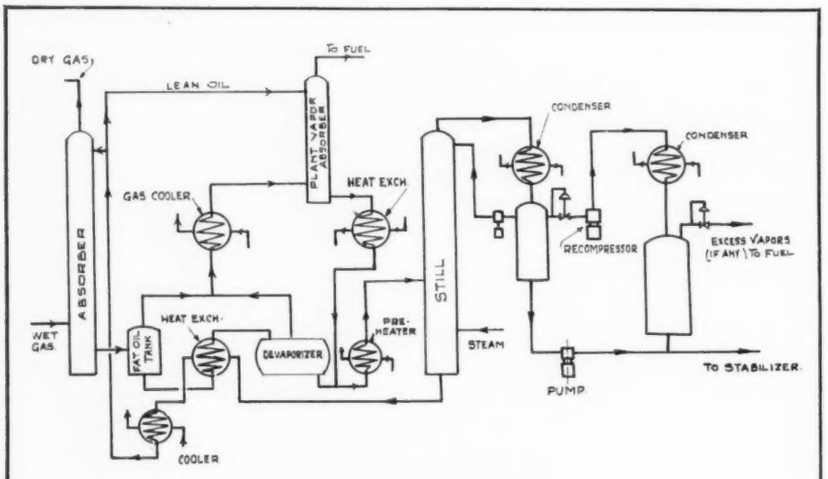


Fig. 4. Flow sheet of reabsorption and recompression of plant vapors

The uncondensed vapors from the main condensers are relatively few and can be recompressed and totally condensed. The condensed product is fed into the stabilizer. One plant producing 100,000 gal. per day of raw gasoline is able to recompress all the vapors from the main condensers with only a 125-hp. compressor. This is a very small load. The lean oil circulation to the main absorbers is 980,000 gal. per day and 360,000 gal. for the secondary or reabsorbers, which operate at only 40-50 lb. It must be understood there is no recycle load in this circuit.

The only difference between a high-pressure and low-pressure plant is that the first flash of fixed gases to the reabsorber must be made by heat after the fat oil passes through an exchanger instead of reduction in pressure in the fat oil tank. Otherwise the treatment is essentially the same.

Stabilization of Gasoline

The processes so far discussed should be operated to give the minimum volume of methane and ethane in the gasoline and vapors to the stabilizer. The usual practice (because of existing equipment and also for best operation) is to feed all products into the main stabilizer used for casinghead production.

Excess overhead condensate (excess over reflux requirements) is fed to a deëthanizing column if essentially pure propane is wanted for a fuel or for blending with normal butane. If pure propane is not required but only a mixture of propane and ethane, instead of a deëthanizing column, the surplus condensate from the main stabilizer can be fed to a depropanizing column. The bottoms from it will then go to the *iso*-normal splitting column.

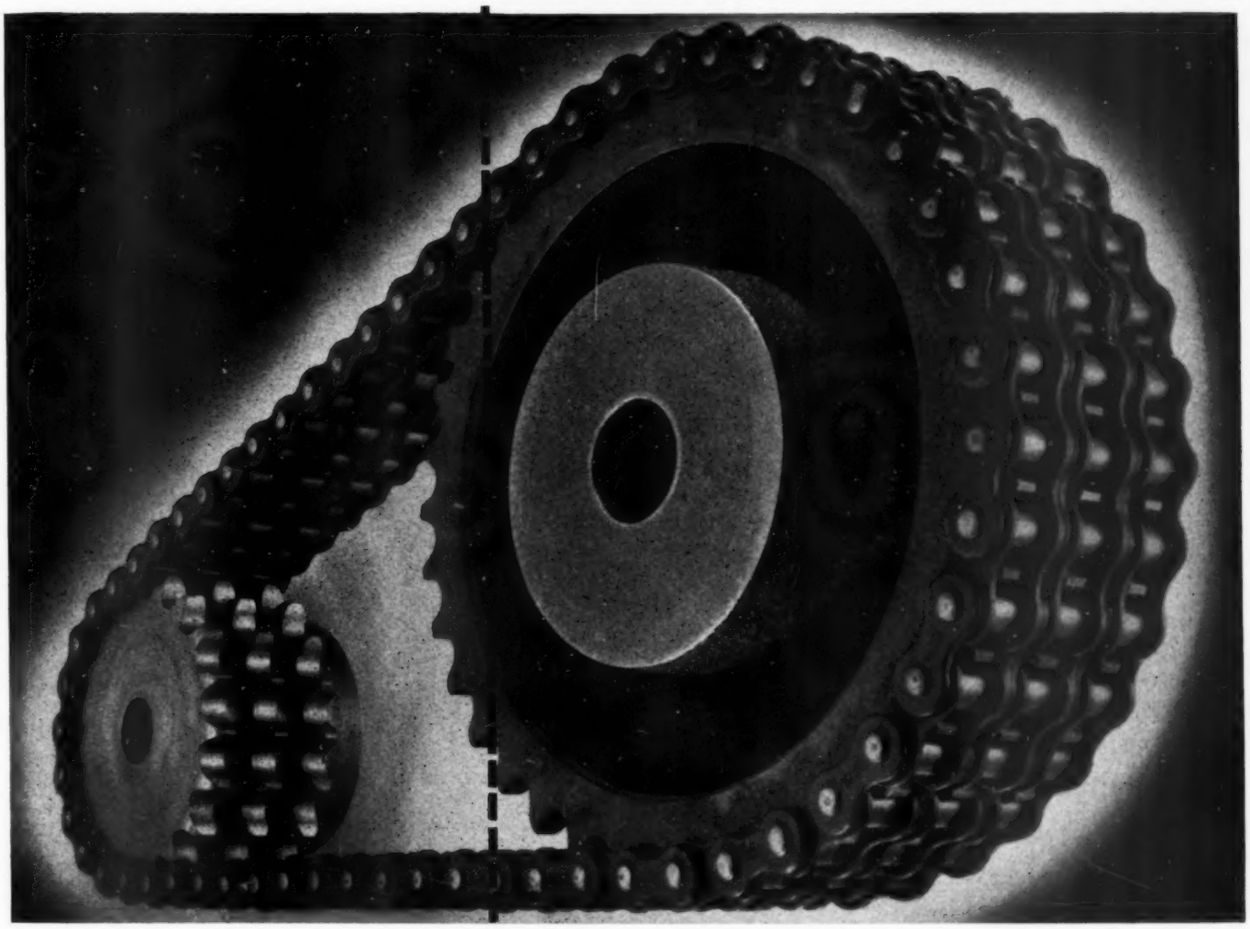
The reverse procedure of first depropanizing the raw gasoline, then removing the *iso*, then the normal with casinghead out the bottom of the last stabilizer is uneconomical in both use of equipment and heat consumption.

Controls

The so-called anticipating control is rapidly coming into use in California. By this is meant controlling an overhead product in a stabilizer from a point below the top plate. Likewise, controlling a bottom product from a point above the bottom plate. As the product on the control plate changes, the controller is able to make the necessary correction before the heavier product reaches the top plate or the lighter one reaches the tower outlet. This method of control is very satisfactory.

——— ☆ ☆ ☆ ———

FULL FUEL TANKS
call for FULL POWER . . .
FULL TIME from all oilfield equipment drives



WHITNEY PRODUCTS

Roller Chain & Sprockets
Silent Chain & Sprockets
Conveyor Chain & Sprockets
Roller Chain Flexible Couplings
Automatic Load Limiting Sprockets
Automatic Drive Tensioners
Woodruff Type Machine Keys and Cutters

Huge reserves of fighting fuel are needed to carry American arms to victory around the world. And in building up these reserves, Whitney Chains carry an important share of the responsibility for full delivery of power to oil field equipment, 24 hours a day. For Whitney Chains are built to carry this responsibility unfailingly . . . built to stand shocks and overloads, and armored for extra-wear resistance and longer life by special Whitney alloy steels. So keep *your* operations free from drive failures and time-losing maintenance, by specifying Whitney on all new equipment and for all chain replacements as well.

. . . and that calls for WHITNEY CHAINS

THE WHITNEY CHAIN & MANUFACTURING CO., HARTFORD, CONN.

P 615.635.3

When Should a Pipe Line Be Coated?

PETROLEUM ENGINEER Exclusive Feature

☆ Determining corrosiveness of soil requires technical knowledge as well as practical experience

by Starr Thayer
Consulting Engineer

QUITE often the engineer is called upon to answer the old question: when should a pipe line be coated? Generally this arises in connection with the construction of a new line.

Obviously the answer is to coat all lines that are to be laid in corrosive soil. The question then arises: how are corrosive soils to be identified and their degree of corrosiveness determined? In areas that have not been previously identified by pipe-line experience, this question indeed becomes a problem. As a result many companies make no attempt to classify the soils but coat all new pipe lines. Some companies lay all pipe lines bare that are in areas known to be fairly non-corrosive and coat the rest, practically without further study.

Classification of Soils

It is doubtful whether there is any soil, embracing any appreciable area, that is completely non-corrosive. Numerous methods have been devised to aid the engineer in classifying these soils. Some methods require considerable time for application and for that reason decrease in value. Generally the engineer is limited in time to make his decision regarding whether the pipe line should be coated. Several methods such as electrical resistance measurements have been made in many cases as well as acidity and moisture content measurements. None of these methods is completely infallible and should be combined with visual inspection. The experienced engineer will be able to recognize the corrosive characteristics of many soils with which he has had previous experience.

Possibly the one reason that makes any soil study inaccurate is the fact that very few soils are of uniform character for any considerable distance. The most bland soils often have clod inclusions that cause the pipe to corrode. A soil sample might not contain one of these clods; in fact, the chances are that it would not. This non-uniformity of soil has probably caused more surveys to fail in their purpose than any other factor.

STARR THAYER

prior to becoming a consulting engineer in 1938, served the United Gas Public Service Company as corrosion engineer for seven years —He received a bachelor's degree in electrical engineering from Iowa State College, was a captain in the engineering corps during the World War, and for many years was an electrical contractor, constructing power plants, electrical railroads, etc.—Thayer was one of the pioneers in the field of protecting pipe lines cathodically, and is regarded as an authority on that subject as well as on corrosion problems in general—Makes his headquarters in Houston, Texas.

Denison and Darnielle of the U. S. Bureau of Standards discuss soil non-uniformity very ably in a paper published in 1938. (Research Paper RP1157.) In one paragraph the statement is made: "A probable explanation for the occurrence of even a small number of leaks in soils in which leaks would not be predicted, is that corrosion did not occur generally throughout the soil type, but was confined to restricted areas of more corrosive soil types that were too small in their extent to be properly classified."

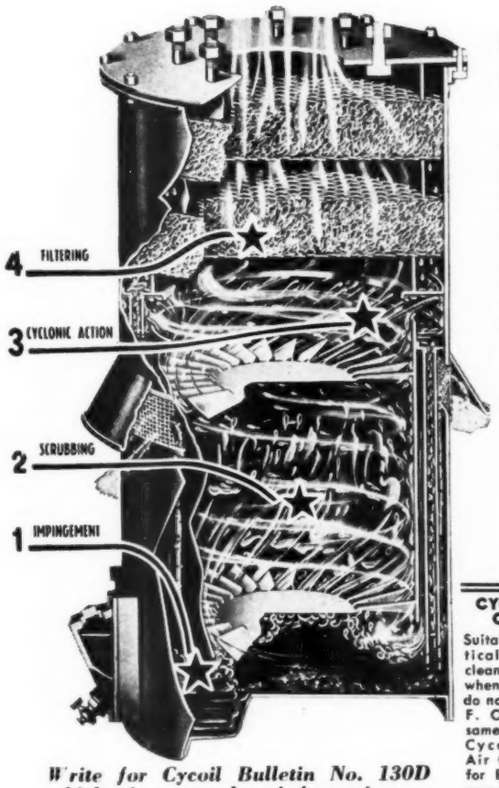
It is evident that the engineer is certainly confronted with a problem when he attempts to predict what the maintenance cost of a line will be if laid bare. This is an economic problem. The cost of the coating application must be justified. On the other hand, it is rather difficult for the engineer to explain leaks in a newly laid line.

When to Coat a Line

As previously pointed out, it is difficult to anticipate corrosion troubles. It is possible to use past experience, however, and perhaps from it can be formulated some conclusions. Before arriving at any conclusions it must be admitted that a good coating will protect a line against corrosion. If it is not agreed that coatings have this protective value, then a corrosion and coating study would be of no benefit.

In the accompanying graph (Fig. 1) it is assumed that a line is laid with a life expectancy of 30 years and that it would cost $1000 per mile to apply a protective coating. This is represented by the straight line "A". The records of one of the largest pipe line companies, as well as one of the oldest, show that it costs approximately $70 per mile per year to repair leaks. Plotting this cumulative cost results in line "B". In this particular instance it may be seen that by the end of the 14th year the cost of repair-

Judged by PERFORMANCE the Cycoil HAS NO EQUAL



Write for Cycoil Bulletin No. 130D which gives complete information on the operation of the Cycoil.

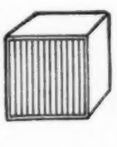
Air cleaner protection is probably more important today than at any time in history. In the war emergencies engines must perform better and must last longer.

For more than 19 years American Air Filters for compressors, diesels, and gas engines have established outstanding performance records. Outstanding among these AAF units is the Cycoil Oil Bath Air Cleaner which was originally engineered to meet the extreme conditions of the dust bowl area. At the left is shown the Cycoil's exclusive 4-way cleaning principle in operation, which assures positive dust protection under the most severe dust conditions. Send for Cycoil Bulletin No. 130D and descriptive literature on all types of American Air Filters for engine and compressor protection.

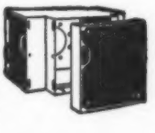
AMERICAN AIR FILTER COMPANY, Inc.
INCORPORATED
384 Central Avenue, Louisville, Kentucky
In Canada: Darling Bros., Ltd., Montreal, P. Q.

CYCOIL GAS CLEANER
Suitable for practically every gas cleaning problem when temperatures do not exceed 140° F. Operates on same principle as Cycoil Oil Bath Air Cleaner. Ask for Bulletin 130D.

PL-H FILTER
is a complete assembly consisting of housing, ready to bolt to intake pipe, and dry cell type filters in which wool felt constitutes the filter medium. Ask for Bulletin 120D.

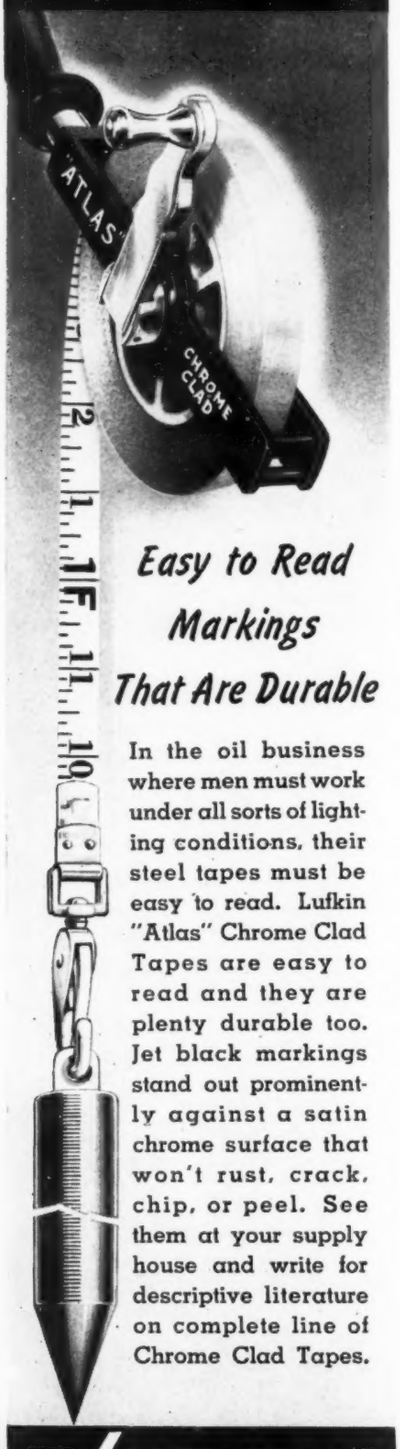


TYPE OCH FILTER
Complete assembly consisting of washable viscous impingement type filters. 1, 2, 3, or more cells are used, depending upon size of cleaning job. Ask for Bulletin 120D.



AMERICAN Cycoil AIR and GAS CLEANERS

"ATLAS"
CHROME CLAD
STEEL TAPES



Easy to Read Markings That Are Durable

In the oil business where men must work under all sorts of lighting conditions, their steel tapes must be easy to read. Lufkin "Atlas" Chrome Clad Tapes are easy to read and they are plenty durable too. Jet black markings stand out prominently against a satin chrome surface that won't rust, crack, chip, or peel. See them at your supply house and write for descriptive literature on complete line of Chrome Clad Tapes.

LUFKIN
SAGINAW, MICHIGAN • New York City
TAPES · RULES · PRECISION TOOLS

ing leaks would equal the cost of coating; also, that at the end of the 30 years about $1100 per mile would have been saved by having these lines coated.

The banker would say that a charge should be made for owning this coating. If interest is allowed on the investment, additional taxes, etc., and the investment retired in 30 years, there would be a carrying charge of about 13 percent. Plotting this cost results in the line "C". This shows that at the end of the 30 years this coating would have cost about $3900 per mile. On that basis it would not pay to coat the lines. If interest is charged against the cost of the coating then it should also be charged against the cost of making repairs. The money spent on maintenance cannot be used to pay dividends. If the cost of making repairs plus the interest on this cost is plotted the line "D" results. At the end of 30 years it arrives at about the same point as "C" on the graph.

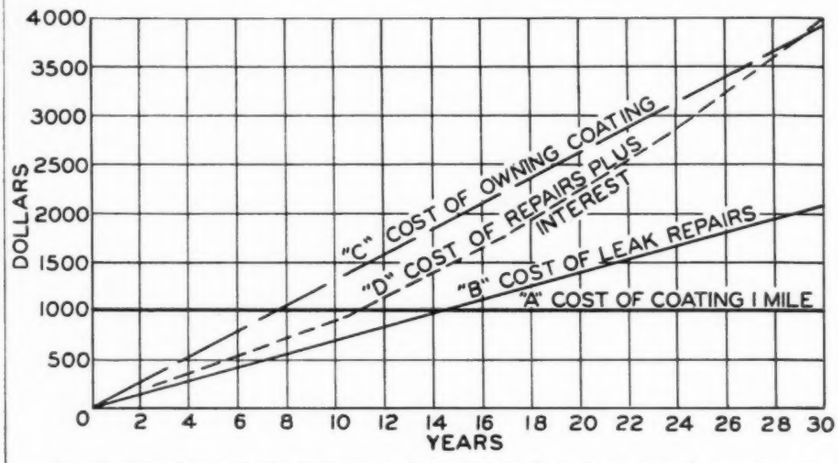


Fig. 1. Graph in which the years of service is plotted against the various attendant costs of a coated pipe line

The figures used here would probably not apply to any other system. Anyone interested in doing so could plot his own graph.

There is one obvious fallacy in using such data as a basis of determining coating programs. If a study of leak frequencies were made it probably would be found that most of the original leaks occurred in a very small part of the lines. As time goes on these leaks would spread until a considerable part of the lines was involved.

Conclusions

In view of the above discussion it would appear that soil surveys should be made and the pipe line coated in the corrosion areas and even in doubtful areas. One large company not many years ago made a very detailed soil study and used this method to determine the areas to be coated. The results were anything but satisfactory. Leaks developed near the ends of the coated sections far in advance of what would have been expected even in the soils that were considered corrosive. The company concluded that so-called "spot coating" merely transferred the corrosion and concentrated it at the ends of the bare sections.

Some years ago another large pipeline company launched a program of reconditioning "hot spots." In these areas the pipe was cleaned and coated through the corroded areas and for some distance beyond where pitting was last observed. Within a very short time the same trouble was experienced; that is, the ends of the bare pipe developed trouble although for years previously there had been no trouble. Possibly other operators have had this same experience. From these data it would appear that spot coating should not be used except possibly as applied to large areas.

These experiences, plus the realization that the corrosiveness of soils is extremely difficult to determine in advance, leads to the belief that there are not many instances in which it is justifiable to gamble with corrosion. Probably not many bare lines have as low a maintenance cost as the one illustrated in the graph; a coating on this line would have effected a substantial saving.

It is the writer's opinion that efforts should not be concentrated so much on the problem of where to coat pipe lines, but rather on the problem of where they should be left bare.

☆ ☆ ☆

THE IMPORTANCE OF *Symbols*

From their easy-to-grip hand-wheels to their generously oversized bodies; —from their extra heavy wear - resisting bronze stems to their husky Union Bonnets;—from their precisely machined bronze glands and extra deep stuffing boxes to their specially constructed discs, O.I.C. Valves will pay you dividends the minute they go on your lines.

Replace now with O.I.C. Join the growing number of users . . . all of whom are saying:

"Oh I See! Lower Costs with O.I.C."

O.I.C. IS PREPARED TO FURNISH YOU SYMBOL INFORMATION ON "END USE"

O.I.C. is in position to help you in determining your proper "End Use" classifications and symbols so that your purchase orders to us may be correctly endorsed.

As a plus-service to the steadily growing number of users of O.I.C. valves, we have available for you a complete, concise and accurate reproduction of "End Use" Classifications and Symbols — their purposes and descriptions, plus general and specific instructions for their use.

You will find this manual a time and trouble saver. For example—if your "End Use" is in the power field, your Symbol may be 9.10; or — in the petroleum field you may require a Symbol 9.20; or — in the chemical processing field your Symbol may be 8.20 and in the paper and pulp industry, it may be 8.90.

Just write to us on your company letterhead, and we shall gladly send you your copy without obligation . . . or you may obtain a copy from your nearest O.I.C. Distributor.

And always remember . . . there's a sturdier O.I.C. Valve for your every "End Use" that will insure you:

★ Longer Uninterrupted Service
★ Lower Replacement Cost
★ Lower Maintenance Cost
★ Minimum Over-all Cost

OIC

THE OHIO INJECTOR COMPANY
WADSWORTH, OHIO
Quality Leaders in Valve Manufacture Since 1883

The Stripper Well Problem

PETROLEUM ENGINEER Exclusive Feature

☆ A discussion of the present-day importance of small producing wells and observations regarding their future place in the oil industry

by James F. Weiler

Concepts

THERE has been much confusion regarding the terms "stripper well," and "marginal well." At the outset it is expeditious to have a general concept of these terms. The following are some of the more common definitions:

"Stripper wells are determined to be that type of operation isolated so as to make relief impracticable, provided, however, that where the total operations with reference to individual ownership is such that the commercial production is not sufficient to maintain ordinary operations, that in those cases relief may be granted solely upon the financial inability of the operator to maintain ordinary operations."[1]

"The word 'stripper' came into use as applied to a well stripping off the last remnant of production that was mechanically and physically possible to pump out of a hole in the ground. Many people talk loosely of 'stripper wells'; what they mean is 'marginal wells,' i.e., wells of small production in which the value of oil produced is very close to the cost of producing it."[2]

"Generally speaking, a 'stripper well' is a well that has declined to a point where the production curve has become a straight line approaching zero. There is no acceptable definition in the industry to indicate a particular kind of well."[3]

" 'Stripper wells' are wells from which the proceeds from the oil sold are so small that they do not cover the cost of production or provide only a small margin of profit for the operators taking into consideration all factors pertaining to the producing branch of the industry."[4]

From the foregoing, the confusion of the two terms is evident. The following definition is believed to be correct, patterned after a definition issued by the U. S. Bureau of Mines.[5]

"Stripper" is solely a physical connotation implying that a "stripper well" is taking out of the reservoir sand the last oil that could be mechanically and physically pumped out.

A "marginal well" is one in which the value of oil produced approaches the cost of production, with very little margin of profit between the financial return from the oil, and the cost of producing it.

JAMES F. WEILER

obtained a B.S. degree in petroleum engineering from the University of Texas in September, 1939, and an LL.B. degree from the same university in June, 1942—Worked as a petroleum engineer for the Texas Railroad Commission, Oil and Gas Division, during the summers of 1940 and 1941, being stationed at Corpus Christi and Kilgore, Texas, respectively—Is now employed by Fulbright, Crooker, Freeman and Bates, Houston, Texas.

To illustrate: a well producing 20 bbl. of low-grade black oil in Wyoming is a marginal well because of the low price of such oil, or absence of market therefor. A well producing ½ bbl. per day in Pennsylvania may be a "stripper," but not marginal because of the high price obtainable for Pennsylvania crude oil.

Also, when prices slump, profitable wells, and stripper wells might be brought into the marginal class.

Summing up, a "stripper well" is a quantitative term; a "marginal well" an economic one."[6]

Number of Stripper Wells

It is impossible to determine accurately the number of stripper wells in the United States today because of the loose terminology employed. There have been many estimates made, however.

In 1934 there were estimates of 326,000 producing wells of which 250,000 produced less than 5 bbl. per day. That is, 76 percent of the wells in this country were of the stripper type.[7] Other estimates varied from 300,000[8] to 350,000[9] stripper wells. The Bureau of Mines estimated there were 321,000 producing wells in 1934.[10]

In 1940 there were approximately 390,000 producing wells in the United States, 286,500, nearly three-fourths, of which are stripper wells.[11] The total reserves in the nation amount to 19,687,379,000 bbl. The stripper wells represent an estimated reserve of 3,602,956,000 bbl., more than 18 percent of the total.

In 1939 in Texas about 50,000 of the 67,000 wells were stripper wells. These wells produced less than 5 bbl. per day.[12]

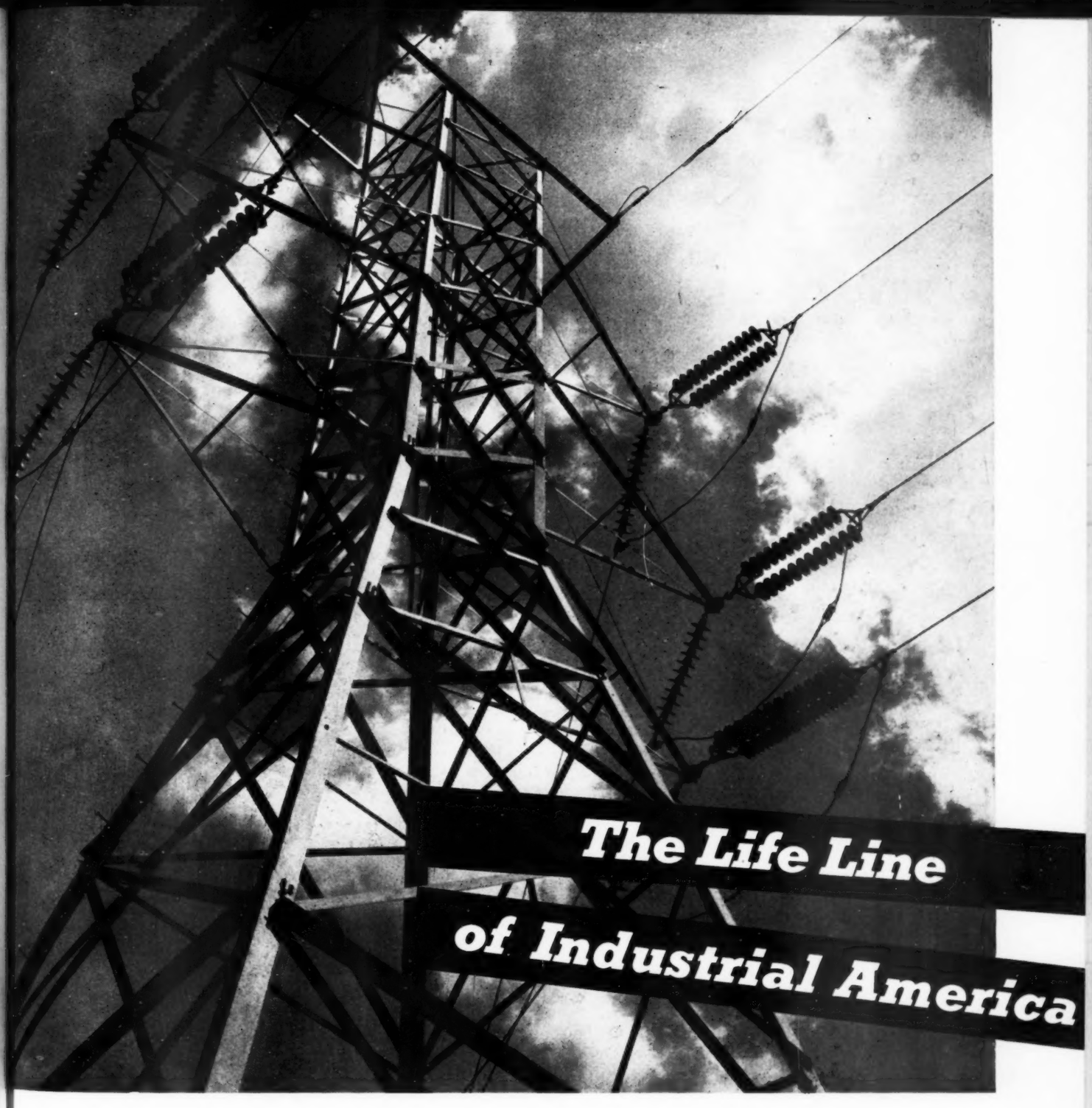
It is interesting to note that in 1934, 76 percent of the wells were of the stripper type, whereas in 1940, approximately 75 percent were of that classification. The survey made in 1940, however, was a very careful, and as accurate a one as could be made, whereas the survey made in 1934 was possibly not quite so accurate.

Most of the stripper wells are owned by independents. It has been estimated that more than 50 percent are so owned.[13] Thus of the 390,000 producing wells of the United States, approximately 75 percent are strippers, more than one-half of which are owned by the independent operators.

General Characteristics

It is frequently said that the gusher of today is the stripper of tomorrow,[14] and undoubtedly that is true. For example, in the Wortham field, Texas, there was a daily production of 153,000 bbl. for the week ending January 17, 1925. Three years later, this field was producing only 2200 bbl. a day, a decline of 99 percent.[15] In the Powell field, Texas, there was a decline in three years from 315,800 bbl. a day to 24,400 bbl., a decline of 92 percent. In the Santa Fe Springs field, California, development, from the peak in 1932 there was a decline of 86 percent in three years. In that particular field, however, subsequent deeper drilling opened up large new production.

Despite these declines, it is to be remembered that there was little or no effective proration in Texas at the



Electric Power means life for American industry. Our great industrial strength has been built around it. Mass production is possible only through its many advantages. Like the circulatory system of the body, Electric Power flows ceaselessly through a great nation-wide network of arteries, providing vital life-giving power to the drill, the drawworks, the pumping well motor, the centrifugal pump, the refinery and thousands of other important operations. How priceless then is Electric Power that is constantly available, 24 hours a day, every day of the year? And when you stop to think of it, there isn't another service in existence that offers so much, for so little cost, as *Utility Electric Power!*

Use Utility Electric Power!

PETROLEUM ELECTRIC POWER ASSOCIATION

Box 1498, Oklahoma City, Oklahoma

time of the drilling of these fields; also, there is no proration in California, hence, the waste was tremendous, and under an effective proration schedule such a rapid decline would not occur.

Stripper wells produce an oil devoid of the dissolved gases that originally gave them a high rate of production.[16] With the release of the gas through high initial rates of flow, blowing to the atmosphere, the oil has gone flat, increased in viscosity, and its rate of flow through the sand is only a small percentage of the original flow. The oil can only be obtained by secondary methods of recovery.[17] These are expensive processes. These wells are considered by many as the backlog of the oil industry, and it is a familiar expression that "you must protect the little stripper well."[18] In fact, many assert that the purpose of conservation is to protect the stripper wells.[19]

Stripper Well Abandonment

In 1929 there were 7482 wells abandoned, which figure is probably higher than for previous years.[20] In 1930, when the depression got under way and the market was flooded with cheap oil, the abandonments increased to 15,676. In 1931, the worst year in the industry, there were 21,603 abandonments, which amounted to a 62 percent excess of abandonments over drilling for that year. Undoubtedly, the percentage would have been even greater if so many abandonments had not occurred in 1929 and 1930.

Practically all wells abandoned were of the stripper or marginal class due to the added cost of extracting the oil and the small return therefor. Of the 11,000 wells owned by The Ohio Company, most of which were strippers, 1000 were abandoned during the 1931 period because of acute economic conditions.[21]

Examining closely the stripper areas during this time, however, it is found that in West Virginia where the daily production of oil per well averaged 0.6 bbl. per day, only 2.9 percent of the producing wells were abandoned during the period from 1931 to 1933.[22] In Pennsylvania the daily production was 0.7 bbl. per well, and abandonment for the same period was 6.7 percent. Likewise in Arkansas where the daily production was 9.9 bbl. per well, the abandonments totaled 27.7 percent. In Louisiana, daily production averaged 22.3 bbl. per well, and abandonments amounted to 30.4 percent.

One reason for the smaller number of abandonments in Pennsylvania and West Virginia is that these fields are old, and practically all production is from stripper wells; also, this crude oil commands a high price because of its paraffin base, which makes it especially good for the manufacture of lubricants. In Arkansas and Louisiana there is more flush production and a lower grade of crude oil selling at a lower price, hence the stripper wells were abandoned much sooner.

Of the abandonments in the United States between 1931 and 1933, 74 percent were made in districts where the average production per well was 10 bbl. a day or less, [23] and in West Virginia and Pennsylvania the abandonments were far in excess of the drillings although water-flooding in the Bradford field, Pennsylvania, influenced the statistics.

Many wells have been producing in Pennsylvania since 1879 and have survived the price curve.[24] Of course wells have been abandoned because of price conditions, water intrusion, and numerous other factors, but a great number of these wells has survived.

Without regard to the cause of these abandonments, it is significant that in 1931 there was an excess of abandonments over drilling of 62 percent, of which abandonments practically all were strippers.

Effect of Price

When the price for crude oil is high a certain number of stripper wells is abandoned, due to natural causes, such as producing too much water with the oil, or because the crude is of low grade and there is no market therefor. The most compelling argument of the industry has been that natural causes cannot be aggravated to the extent that they will result in excessive abandonments over drillings as occurred in 1931 when the excess was 62 percent throughout the United States;[25] rather the cause is economic.[26]

Testimony taken before the various Congressional Committees are replete with statements, the following of which are typical:

Dr. Katherine Carmen in 1934 stated that "Stripper wells cannot exist in the economic structure unless the price structure is up at some minimum, and large amounts of petroleum are irrevocably lost to the Nation by the premature closing in of stripper wells during a time of low price."[27] For support of her statement, Dr. Carmen advances the fact that in 1930 the average price of oil was $1.19 per bbl.; in 1931, $0.64 per bbl. with a 62 percent excessive abandonment over drilling.

Amos L. Beaty[28] in 1934 stated that: "There is undoubtedly a great abandonment of stripper wells when commerce is depressed and prices are low."

Dr. Joseph E. Pogue[29] in 1940 stated that: "Price collapses have usually been the cause for the abandonment of stripper areas, rather than persistent declines in physical production to very low levels.

Col. Ernest O. Thompson[30] in 1939 stated: "Now, when the price drops so low the stripper well cannot operate, then you are driving out these two or three hundred thousand wells, certainly 200,000 of them could not operate, and cutting off forever the two or three thousand barrels per day they produce."

Glenn E. McLaughlin[31] in 1940 contended: "The abandonment of wells because of low price of crude has been estimated to constitute a considerable economic loss."

These contra-arguments have been advanced.

W. S. Farish[32] in 1934 argued: "Low value for crude petroleum over a protracted period may cause the abandonment of some stripper wells prematurely, although the record shows that we have stripper wells in operation that have been stripper wells for two generations." Also, Farish continued: "No oil field in this country has been completely abandoned. This is true in spite of the fact that throughout the period of producing history there have been recurring periods of overproduction and low prices."[33]

Jake Hamon[34] testified in 1934: "I have made a number of stripper wells, buy them all the time, they make money. If you don't believe me, try to buy some."

T. P. Thompson[35] stated in 1934: "We have had stripper wells since 1879, and they survive the price curve. Some do, and some do not."

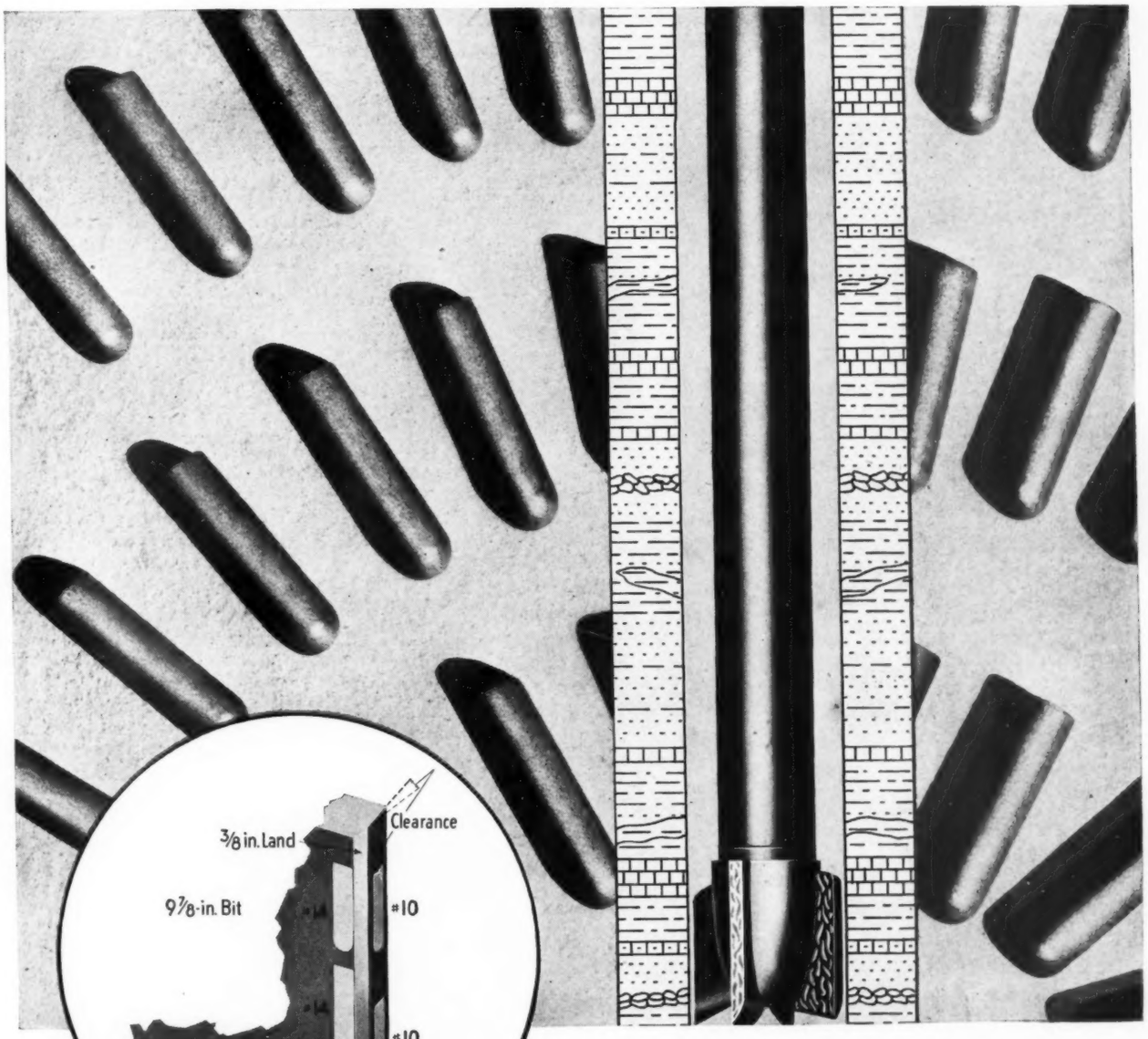
Hopkins and Stone published[36] an interesting comparison of three fields, one flush, one semi-flush, and one stripper for the years 1934 and 1937 based on average production in barrels per day per well, the cost of production, and the market price therefor:

State	Year	Avg. oil. prod. per well per day, in bbl.	Net cost of avg. sale	
			Prod. per bbl.	Price per bbl.
Kansas.....semi flush	1934	6.9	$0.882	$1.031
	1937	9.5	0.970	1.230
Louisiana Gulf Coast.....flush	1934	over 27.0	0.753	0.990
	1937	200-500.0	0.705	1.150
West Virginia.....stripper	1934	0.6	2.113	2.089
	1937	0.6	2.300	2.280

It is difficult to comprehend how the average operator in West Virginia can continue in business. The producing wells of West Virginia are uniformly small pumpers with only about 500 of 19,000 producing more than 1 bbl. of oil per day, which sold early in 1938 at a loss of $0.02 a bbl. On March 7,

USE HAYSTELLITE INSERTS

for more efficient Drilling Tools



A typical application of Haystellite inserts is shown above.

Haystellite inserts are available in a wide range of types and sizes. One type is shown here, actual size.

FOR VICTORY BUY UNITED STATES WAR BONDS AND STAMPS

HAYNES STELLITE COMPANY

Unit of Union Carbide and Carbon Corporation

New York, N. Y. UCC Kokomo, Indiana

Chicago — Cleveland — Detroit — Houston — Los Angeles
San Francisco — Tulsa

HAYSTELLITE CAST TUNGSTEN CARBIDE DIAMOND SUBSTITUTE

The words "Haystellite" and "Haynes Stellite" are registered trade-marks of Haynes Stellite Company.

1938, the price was reduced to $1.65 per bbl., and on June 13, 1938, to $1.40 a bbl., $0.90 below the estimated average cost of production.

These wells have been able to survive only by ignoring depletion and obsolescence and cutting operation costs to the bone.[37] The majors usually farm out these wells because their fixed overhead is high, whereas the cost of producing the wells would be materially reduced if controlled by some small company or individual.[38]

The policy of the government is indicated by Secretary Ickes' statement: "Many of these wells have held on, operating at a loss in the hope that a beneficent government would do a beneficent thing."[39] This statement was made in 1934.

A tentative conclusion seems to be that despite the price structure at any particular time, many wells are abandoned because of natural causes; that a depressed or low price does accentuate this to some extent, but that the accentuation has been greatly exaggerated. Of course, when a well is no longer profitable to produce, there is only a certain length of time that anyone will produce that well in the hope of a more favorable price. But many stripper wells are profitable, and there seems to be evidence that an investment in stripper-well properties is a safe, long-term investment.

The problem is rendered more complex by the fact that even though a stripper well is operating at a loss, a higher allowable might be granted to the lease with the well than without it, which allowable can be made up by other production. The cost of moving equipment to new locations and the convenience and economy of the old location might outweigh abandonment, as well as the additional considerations that if the well is shut in the lessee would lose the lease, contingent future profits that would result from a future price raise, and the possibility of a deeper producing horizon being developed.

Aside from these factors, and many more that this article does not encompass, it may reasonably be concluded that wells are abandoned because they no longer are profitable due to natural causes, and that a price collapse will accentuate abandonment to a certain extent, but that abandonment of stripper wells because of a depressed price has been greatly exaggerated.

Effect of Overproduction

When excessive quantities of crude oil are thrown upon the market, prices decline to the point where it is no longer profitable to operate.[40] Amos L. Beaty contends that these no-longer-profitable stripper wells are abandoned as a purely economic matter, and that the oil in the sands, which otherwise would have been extracted and utilized, is permanently lost.

The East Texas field was discovered in 1930, and it would be well to scrutinize the statistics for the years 1929, 1930, and 1931. In 1929 there were 7482 abandonments; in 1930, when the flood of cheap oil increased, the abandonments amounted to 15,676; and in 1939 the abandonments totaled 21,603 wells. The average price of oil in 1930 was $1.19 per bbl., and in 1931 it was $0.64 per bbl.[41]

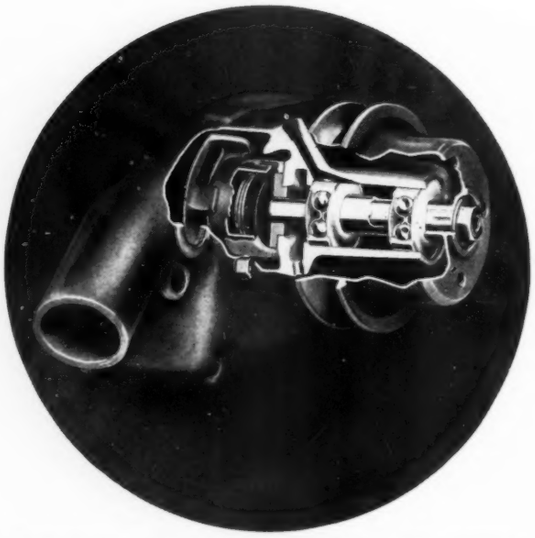
From the foregoing statistics it is evident that overproduction of oil depresses and lowers the price, which in turn accentuates the abandonment of stripper wells.

Need for Preservation

Assuming that overproduction causes depressed prices, and that stripper wells are abandoned because of low prices, should a high price be sustained? That poses the question, wouldn't it be better to drive out these marginal businesses than to allow them to continue in business with a resultant higher price?

In the broad field of economics a policy that would undertake to sustain

Internally Sealed Water Pump!



This internally sealed NO-LEAK water pump prevents disastrous leakage. The impeller is mounted on ball bearings to maintain alignment and the carbon seal prevents leakage by centrifugal action.

Other important features in Red Seal Continental Engines for oil field service are — directional cooling — full length water jacket — interchangeable bearings — counterweighted crankshaft with precise balancing — pressure lubricated barrel-type tappets — and individual porting for quick starting, maximum power, economy and flexibility.

Sales and Service Facilities

Dallas: National Welding & Grinding Co. *Longview:* Standard Tool & Machine Co.
Houston: C. Jim Stewart & Stevenson Co. *Wichita Falls:* Wichtex Machinery Co.

Continental Motors Corporation
MUSKEGON, MICHIGAN

a high cost producing unit when a low cost producing unit would take its place cannot be defended.[42] The petroleum industry's answer, and the policy of the government as indicated by Secretary Ickes, is that oil is an exception, a natural resource that must be viewed from a conservation standpoint, a long-term concept.[43] Otto D. Donnell voices a similar view stating: "As a conservation measure we should go to any extent to keep these stripper wells in production."[44] A similar position was taken by W. J. Brundred[45] when he testified that "stripper wells are the backlog of the industry, contacting a vast area of reserves which, due to much higher lifting costs in comparison to flush fields, will be available only at crude prices that will support recovery costs. National conservation requires that these wells be preserved; any other policy is waste of the worst sort."

Opposed to these statements is one by J. Howard Pew[46] that "if legislation is passed that will stabilize the price level so that stripper wells can live, that violates the sound principle that the government ought not to adopt a policy for the purpose of permitting a high cost producing unit to stay in business. And oil, although irreplaceable, should not be an exception."

The Kansas Corporation Commission takes the following attitude:[47]

"Most of the Kansas wells are in the stripper class, regardless of the definitions used. These many thousand wells have yielded small production at low prices, but furnish employment to over one-half the field workers and one-third the total allowable. The selfish unwarranted statement has been made that this type of stripper-well production should be abandoned because new fields can supply cheaper oil. Such a destructive policy would quickly and permanently increase the price of petroleum products to the consumer. The national interest demands that this great source of future oil supply should be conserved."

Another argument advanced by Jake Hamon in 1940, which appears to be of some significance, is the employment angle.[48] Most of the stripper wells of the country are owned and operated by independents, or small oil operators. For many of them stripper wells are their only production, and, in fact, their sole source of income. A number of them live on the lease with their families and act as owner, gauger, pumper, and well puller. Anything that affects the production of their small daily ration of oil directly and vitally affects the slim margin of income by which they and their families live. Furthermore, there are scores of stripper well communities throughout the oil country. With the golden days behind the town depends upon the income from the stripper wells as redistributed to their retail merchants, store owners, professional men. Also, much of this production has been operated at a loss by large companies with a fixed overhead. Subsequently it was taken over by a former employee on a friendly farm-out basis, the former employee promising to pay the owners on a portion basis of the income. Thus these operators have the added cost of amortization of their investment. Furthermore, the older a well is, the greater the cost of upkeep because of pulling sucker rods, repairs, and installation of secondary methods of recovery with the attendant supervision necessary.

Be that as it may, the employment angle should be given very little weight. To that extent the stripper well should be abandoned as a high cost unit in a competitive field. But a stripper well is not analogous to the usual marginal business. Inasmuch as the supply of oil is a limited natural resource, the facts that more than three-fourths of the wells in the country are of the stripper class, that 18 percent of the reserves attach to strip-

with Reilly Primer and Pipe Enamel

● Gas, oil and water lines coated with REILLY Primer and Pipe Enamel are lastingly protected under all conditions of soil and climate. REILLY Enamel bonds firmly to the metal, providing a smooth, tough coating that effectually resists abrasion and soil stress, withstands extremes of temperature, and prevents corrosion caused by moisture, electrolysis, soil acids and alkalis . . . On the inside of water mains and conduits the smooth, mirror-like REILLY lining prevents incrustations and tuberculation and assures permanent full-capacity flow . . . REILLY coal tar paints give equally effective and economical protection to tanks, stacks, structural steel and all metal exposed to atmosphere, corrosive vapors and gases . . . Booklet describing REILLY protective coatings sent on request.

Reilly COAL TAR PRODUCTS

17 PLANTS
to Serve
the Nation

REILLY TAR & CHEMICAL CORPORATION
Executive Offices: Merchants Bank Building, Indianapolis, Indiana
3513 S. DAMEN AVENUE, CHICAGO, ILLINOIS · 500 FIFTH AVENUE, NEW YORK, N. Y. · ST. LOUIS PARK, MINNEAPOLIS, MINN.
SEVENTEEN · PLANTS · TO · SERVE · YOU

per wells, that the cheapest known substitute (obtaining oil from shale) is many times the cost of stripper well production, and that if stripper wells were abandoned the price of oil would increase as the flush fields became depleted and of the stripper class, it appears that the stripper wells should not be abandoned because of a very low price. A long-term view of the picture should be taken. Of course it is not contended that all wells should be retained, but that only a low price as determined by flush production should not control, if such a price structure would cause abandonments. Most of these wells could possibly be shut-in for the duration of the depressed period. As to whether they can be utilized after a shut-in will be discussed later. Suffice it now to say that most wells could again be produced. As to depressed prices, there have been some abandonments due to this cause, but the number has been greatly overstated.

From the foregoing reasons stripper wells should be preserved, but a high price is not needed to keep operators from abandoning such wells, and if such wells are shut-in for a short period, the well can again be produced.

Effect of Proration

A consideration of proration is outside the scope of this article, but a few incidental effects of proration on stripper wells should be considered. Extensive drilling, open flow, and blowing to atmosphere have been some of the chief causes of waste, and the necessity for "putting the well on the pump." No one today would seriously contend that we should not have conservation (as distinguished from stabilization).

It should be remembered that the location of wells and the rate of flow determine the rate and direction of water intrusion.[49] If a field is produced with a minimum number of wells advantageously located and at a rate that will exhaust the reservoir in approximately 20 years, many engineers have estimated that 90 percent of the recoverable oil can be obtained by flowing at a cost between one-half and one-third the cost prevailing under close spacing conditions and resultant allocation of marginal proration quotas.[50]

Dr. Pogue[51] estimated that the daily allowable for flowing wells in Texas, exclusive of East Texas, would be 31.82 bbl. by 1942, and if spacing were increased from 10 to 20 acres, the allowable would be 42.9 bbl., or about 33 percent greater.

With an optimum-rate control of flush fields the importance of the stripper-well argument will decline, for the properly produced oil pool will leave a less persistent legacy of stripper wells, thus rendering the unrecovered reserve in the stripper stage of less relative importance than it is today.[52]

As to the future, an effective spacing and optimum rate of flow of wells will diminish the stripper-well problem greatly, if not completely solve the problem. This is the key to the solution.

Also, the conservation laws of various oil-producing states provide in most instances that the regulatory body shall not restrict the production of wells below a fixed amount per day. These are termed marginal allowables.[53] Two purposes are embodied in such provisions: (1) As the reservoir energy has already been expended, there is very little or no energy to conserve, and any production has to be obtained by secondary methods, hence no conservation could be accomplished, and (2) To allow a sufficient production to permit the well to operate and make available the oil that would be recovered through continued operation, and which could not be accomplished were the production restricted and the income from the well insufficient to continue operation.

The first purpose appears sound, but the premature abandonment because of restriction in many cases is just a myth. This will be illustrated by the East Texas field discussed later.

They said America was "soft" —that our easy living would make us easy *licking*.

But cocky American fighting men proved them painfully wrong at Wake, Midway, Bataan. And the same factories that produced our peacetime comforts are geared today into the greatest war industry the world has ever seen!

Production is military power. *And electric power is production.* America can produce the planes, tanks, ships and guns to win this war because America has *five times the electric power it had in the last war* — more electrirc power than all the Axis and conquered countries combined.

For that you can thank the quiet, competent men who manage America's electric companies. They were *ready* when war came — and their practical, proved experience will help keep America's war machine humming on the high road to Victory!

SOUTHWESTERN
GAS AND ELECTRIC COMPANY
General Offices: Shreveport, Louisiana

Recovery After Shut Down

Another familiar statement of the oil industry is that stripper wells must be operated continuously. Typically, O. D. Donnell[54] states: "If they (stripper wells) are shut down through economic pressure from the flush and semi-flush fields, they are permanently lost."

It is true many wells are lost if shut down especially when there is salt-water intrusion that causes coning; also, due to the fact that the movement of oil through the stratum has ceased, the viscous oil, devoid of gas, is difficult to start flowing again.

Clyde I. Layton[55] echoes the industry when he contends: "The well must be drained every day to get full recovery. If you miss pumping four or five days, you cannot make it up. Also, casings are old in these wells, and if the wells are pumped every day, any leaks can be quickly found and repaired. If water stands in the well for two to five days, the well is ruined."

Generally when a well is abandoned, the casing is pulled and the well is plugged. If the well is not properly plugged, salt water may flow into the sand from a higher stratum and ruin the sand. Today, however, all states have regulations that obviate this difficulty.

There is also the contingency that if the well is shut-in for any length of time the lessee might lose the lease. Of course the number of successive days of non-production to terminate the lease will vary in each particular instance, and in several jurisdictions the production will have to be profitable. This is a matter of contract and judicial interpretation, and is an important factor. This argument, however, is not so compelling in flush and semi-flush areas.

Unless salt water is present most wells can be produced after a shut-in,[56] and even if water is present could be pumped-out occasionally, but in that case the well could only be shut-in for a limited time.

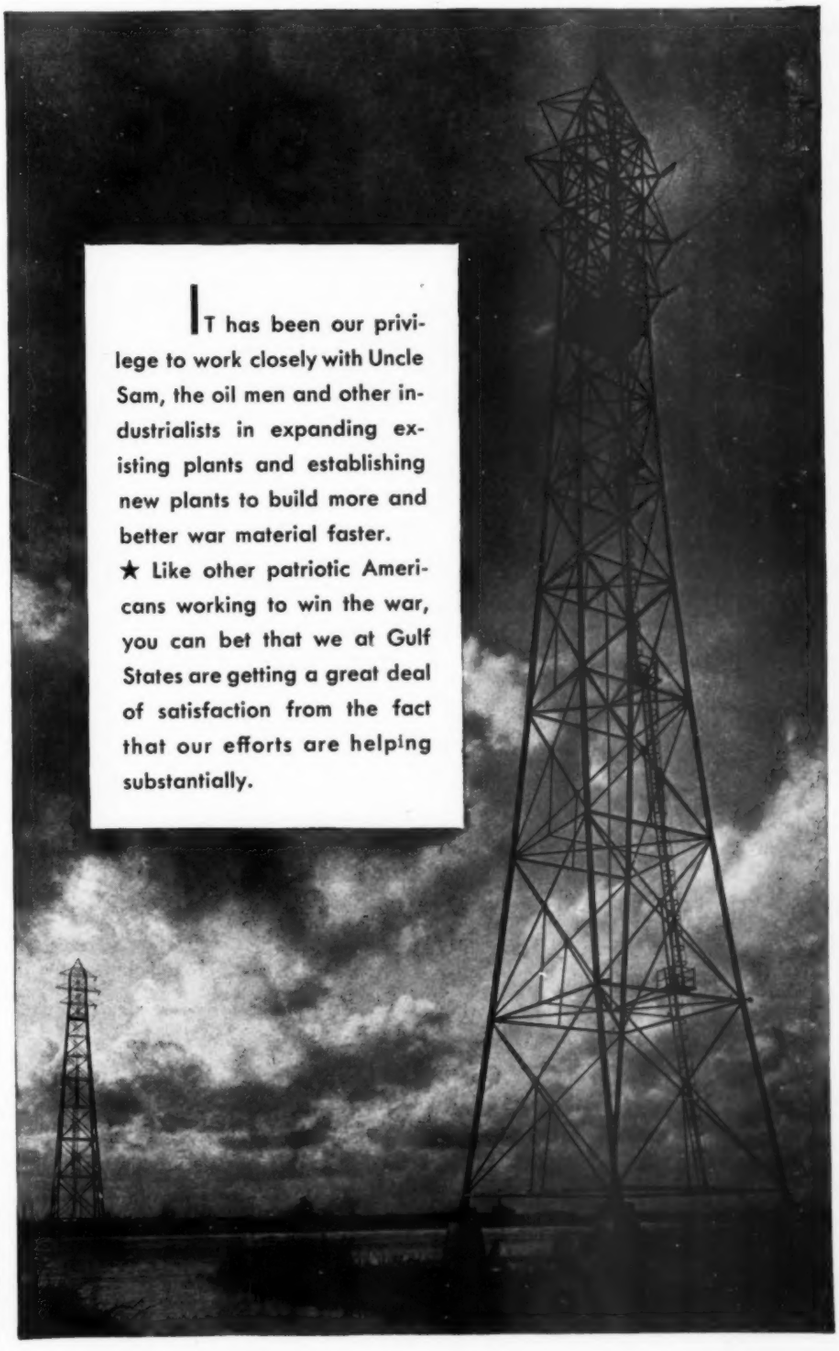
O. D. Donnell[57] testified that "some wells in Wyoming have been shut down for five years, but there is no water to contend with there." Dr. Pogue[58] contended that the oil in most cases will still be available for secondary methods of recovery after a shut down period, and W. J. Brundred[59] stated that few areas will justify a second crop of wells as the virgin rate of flow can never be obtained to aid in recovering the large investment that such redrilling would entail.

A factor to be considered is that if a well is shut down for a period of five years, the interest on the idle equipment would increase the ultimate cost of production, and if corrosive elements were present, new casings, sucker rods, tubing, and pumping equipment would have to be installed. But most wells could be produced after a shut-in unless water were present, and a large number of those wells could be reproduced by water-flooding and other secondary recovery methods.

Secondary Recovery

By secondary methods of recovery generally is meant that the well has ceased flowing, and some device, usually a pump, is installed to act as an artificial stimulus to lift the oil from the face of the reservoir sand to the surface.

As by definition a stripper well is a small well producing from a reservoir whose gas energy has been expended and the water drive is not forceful enough to give flush production, it is already "on the pump." Also, under the Texas Marginal Well Statute,[60] which permits recovery allocated on a depth basis although not expressly made so by statute, it has been construed by the courts not to include a flowing well of less than the marginal well allocation.[61] Hence, for the purpose of this article, secondary methods of recovery shall be construed to mean rejuvenation of a well already "on the


IT has been our privilege to work closely with Uncle Sam, the oil men and other industrialists in expanding existing plants and establishing new plants to build more and better war material faster.
★ Like other patriotic Americans working to win the war, you can bet that we at Gulf States are getting a great deal of satisfaction from the fact that our efforts are helping substantially.

pump" or being produced by some other artificial stimulus.

The most effective restorative methods have been shooting in campact formations, acidizing in limestone or dolomitic strata, plugging when there is a drainage of water from a higher formation to a lower one, installing new equipment to handle additional quantities of water when emulsion difficulties occur, and injection of air, gas, or water to give an effective drive to the oil through the reservoir sand.[62]

The petroleum industry, speaking through W. J. Brundred[63] generally concedes that the rate of flow can be increased by secondary recovery methods, such as repressuring or rejuvenating sands with gas or water, the most striking example of which is the old Bradford field in Pennsylvania,[64] where water-flooding commercially developed a larger reserve of oil than was extracted during the last 70 years by conventional flowing and pumping. But there is always present the cost angle. The problem is typically stated by Harold B. Fell:[65]

"It is true that some of these wells could be redrilled or made to produce by the application of some of the modern methods of recovery, but when maximum recovery of a well is only a few barrels a day, or as little as one-eighth of a barrel (as is the case in many instances) it is self-evident that the investment in new equipment would not be recovered in any reasonable period."

Although each particular well is an individual problem it is believed that the following statement by Parke A. Dickey and Lawrence S. Matteson[66] effectively refutes that contention:

"The future of the oil industry in Pennsylvania depends upon the wider application of water, air, or gas injection to stimulate oil production. The great majority of wells not so stimulated have a very low daily production, and are operated at a very low profit or at a loss in the hope that price will advance or that secondary methods of recovery will be applied. In districts where secondary methods are not generally used, large numbers of wells are being abandoned as unprofitable to operate. The majority of unstimulated wells are at or near their economic limit."

Such a course entails unit operation, but it is not the purpose of this article to discuss that particular aspect of proration.

Ingenious engineers can do much to aid the stripper-well situation in the future. The field is by no means exhausted, and advancements in efficiency of production are continually being introduced to the industry. Dickey and Matteson[67] describe a novel use of secondary methods employed in a closely drilled field subject to corrosive water sands. Several wells were advantageously spotted, filled with junk steel, and used for cathodic protection of casings of nearby wells. With the high price of steel, and the general unavailability of steel because of the war effort, it can readily be seen that such a practice is economically sound.

The Texas Theater

The general scheme of the Texas statute authorizing proration of oil production is constitutional,[68] and the statutes authorizing the Railroad Commission to make and enforce such rules, regulations, and orders as the Commission may deem necessary for conservation of crude oil, and natural gas, and to prevent waste is likewise constitutional.[69] In Texas the landowner owns the oil and gas in place beneath his land,[70] but a landowner cannot enjoin drainage of oil from under his land; his remedy is self-help, i.e., drilling an "off set."[71]

Marginal wells are exempt from curtailment below certain quantities roughly proportionate to the depth of the well, ranging from 10 bbl. for a well not deeper than 2000 ft. to 35 bbl. for a well deeper than 8000 ft. In

The new Jones coupling, shown above, has built into it a smooth hardened and ground surface to resist wear and fatigue.

The same coupling (above) that has been pounded has the hard case shattered and cannot effectively resist fatigue.

Picture of a MAN AT WORK . . . FOR THE AXIS!

The photograph above is from a motion picture made by The S. M. Jones Company a few years ago to show proper care and handling of sucker rods. The man is "Rodney," a fictitious, humorous character, who did everything wrong. However, abusive practices have proven costly. Sucker rod steel is as important to Victory as rubber—and who can estimate the value of oil in relation to the Victory Effort?

Get Better Service, Longer Life, By Following These Simple Rules:

1. Use proper snap wrenches — do not hammer couplings.
2. Cull out bent, pitted or fatigued rods.
3. Be sure pins, boxes and couplings are clean before re-running. One ruined joint means 25 to 50 feet of ruined rods.
4. Rod Hangers should be used wherever possible. When no hanger is available rods should be pulled and laid down in singles.
5. Rods should be properly supported at at least four points when laid down or transported.

The S. M. JONES Co.
JoneSuckeRods
General Office and Factory, Toledo, Ohio — Sales Office, McBirney Bldg., Tulsa, Okla.

East Texas, by special rules,[72] the curtailment orders have been made specifically inapplicable to marginal wells, their quotas determined by marginal-well law. Such wells are also exempt from curtailment of production under the Gas-Oil Ratio Law.[73]

As mentioned, however, a flowing well producing 20 bbl. (East Texas) of oil a day or less is not a marginal well within Art. 6049b, R. S. 1925 prohibiting the Railroad Commission from restricting production of a marginal well as defined in the statute, and the Railroad Commission is without authority to classify such a well as marginal.[74]

The validity of the marginal well statute has never been directly challenged. The apparent reason is that owners of flush production realize that some day their flush wells will be of the marginal type. There is dictum in one case to the effect that the marginal well statute is not patently invalid as the legislature could make a separate classification of such wells, and in view of the expense of operating them by pumping, and of their probable short life, a fixed allowable granted to them is not arbitrary.

This marginal well statute was passed as an economic measure when the price of oil was low. Now the price is considerably higher. Furthermore, depth alone is an arbitrary figure upon which to allocate production. The difficulties and expense of drilling in different areas for the same depth is great. There is a similar discrepancy between costs of recovery in different districts. In Texas, a statutory marginal well is a profitable investment. A strong argument could be made along these lines to invalidate the statute.

The effect of the marginal well on proration is remarkably illustrated by the Texas schedule.

As of January 1, 1938, the total allowable for the State of Texas was 1,388,575 bbl., of which 1,082,770 bbl. were required to be alloted as minimum allowables by the marginal well act, leaving only 305,805 bbl. to be prorated. In other words, the marginal well act controlled the allocation of 78 percent of the allowable production of the state, whereas the proration laws controlled only 22 percent.[75]

Comparing the statistics with September 1, 1939, shows that the brunt of the recession in market outlet during that period fell on the proratable wells. Between September 1, 1937, and January 1, 1938, the state-wide allowable decreased 90,217 bbl., yet the daily quantity of marginal oil was required to be increased 73,783 bbl. because of the 3,474 new wells drilled during that period. The state-wide average of proratable oil consequently fell from 10.56 to 6.68 bbl. a day.[76]

The East Texas picture is even more extreme. On January 1, 1938, the daily allowable was 491,852 bbl., of which 482,385 bbl. were absorbed by the marginal allowance, leaving only 9,476 bbl. to be prorated among 23,951 proratable wells. The proration laws thus affected less than 2 percent of the production, and less than ½ bbl. per well in East Texas. Although the three-judge federal courts of Texas have insisted that the allowable of proratable oil for a good well must be higher than a poor well,[77] the marginal well statute has forced the Railroad Commission to deal with more than three-fourths of the State's allowable and with 98 percent of the East Texas production on a basis that ignores any distinction between good and bad wells.

Thus it is evident that a statutory marginal well in Texas is a highly profitable investment.

Conclusions

Of the producing wells of the country 75 percent are stripper wells that comprise 18 percent of the reserves. Of the total abandonments practically all are stripper or marginal wells, and a decreased price and overproduction in 1931 accentuated an excess abandonment of 62 percent over drilling,

20" O.D. Steel Pipe in Colorado

EAST, WEST, NORTH OR SOUTH

Everywhere in the United States you will find HILL-HUBBELL Protected Steel Pipe installations doing valuable service for the oil and gas industry.

HILL-HUBBELL factory processed pipe protection, like any other machine product, embodies the qualities of precision construction.

HILL-HUBBELL Coated-And-Wrapped steel pipe is produced at these leading mills:

Jones and Laughlin Steel Corp.
National Tube Company
Republic Steel Corporation
Spang-Chalfant, Inc.

For the maintenance of uninterrupted pipe line service, specify HILL-HUBBELL Coated-And-Wrapped Steel Pipe.

Write today for detailed information contained in "THE BOOK OF PIPE PROTECTION."

GENERAL PAINT CORPORATION
HILL, HUBBELL & CO. Division · Cleveland, Ohio
· EXPORT OFFICE: SAN FRANCISCO, CALIFORNIA, U. S. A. ·

but abandonments because of depressed prices are greatly overstated. Many stripper wells are profitable. The marginal business argument is not applicable because a natural resource is being depleted. The marginal well cost, however, could be eliminated under an optimum-rate limitation for production. These wells could be shut-in for the duration of the low price period, and most could be produced again unless water problems were present, and by more efficient secondary recovery methods, the total recovery would be considerably greater and more economic.

In Texas, the marginal well law should be revised taking into consideration all economic factors, not just depth, so that the wells can be prorated on an optimum-limitation schedule.

In the future the importance of the stripper well argument will decline under optimum-rate control of flush fields, for the properly-produced oil pool will leave a less persistent legacy of stripper wells, thus rendering the unrecovered reserve in the stripper stage of less relative importance than it is today. Therein lies the key to the stripper well problem.

The present government policy is indicated in a publication in *The Petroleum Engineer*, March, 1942[78], in which a sub-committee of the Petroleum War Council appointed by Petroleum Coördinator Ickes studied ways and means of increasing oil reserves and preventing abandonments of marginal wells. The sub-committee found that a depletion allowance enabled the industry to continue exploration activities and thus find new reserves, and enabled operators of marginal wells to keep on producing and thereby maintain the continuity of their output for war purposes.

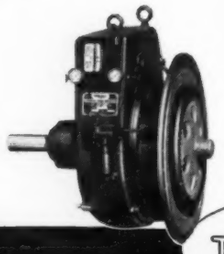
SERVICE

3 direct FACTORY BRANCHES assure prompt service to Mid-Continent oil fields

1. PREVENTIVE MAINTENANCE—Now more than ever before, frequent inspection and necessary adjustments should be made to prevent costly failure and loss of valuable time later. Where excessive wear is evident parts should be replaced.

2. COMPLETE OVERHAULING, if needed, will be handled by competent men, in the minimum time. Call any one of the three branches listed.

3. PARTS AND SERVICE—Ample parts stocks and factory-trained men are available, at Tulsa, Dallas or St. Louis, to handle the service needs of any Twin Disc product in the mid-continent territory.



TWIN DISC CLUTCH CO.
Racine, Wis.

References

1. Harvey C. Fremming, president, International Oil Worker's Union, Washington, D. C. Hearings before a subcommittee of the committee on Interstate and Foreign Commerce, House of Representatives, 73rd Congress, p. 303, 1934.
2. Dr. Katherine Carmen, petroleum economic analyst, Petroleum Administration Board, Washington, D. C. Hearings, p. 404, 1934.
3. W. J. Brundred, vice-president, Central Pennsylvania Oil Producers Association of Oil City, Pennsylvania. Hearings, p. 612, 1934.
4. H. B. Fell, executive vice-president of the Independent Petroleum Association of America, on behalf of the National Stripper Well Association as executive vice-president of that association, Hearings, p. 1509, 1934.
5. Abandonments of Oil Wells and Leases in the U. S. from 1931 to 1935, U. S. Bureau of Mines, Hearings, p. 412, 1934.
6. *Ibid.*
7. Wirt Franklin, president, Franklin Petroleum Company, Oklahoma City, Oklahoma, Hearings, p. 1395, 1934.
8. Amos L. Beaty, chairman of the Planning and Coördination Committee of the Petroleum Industry under the Code, Hearings, p. 214, 1934.
9. See note 1, *supra.*
10. See note 5, *supra.*
11. *Oil and Gas Journal*, January 25, 1940.
12. Col. Ernest O. Thompson, member of Texas Railroad Commission, T. N. E. C. Monograph No. 39, p. 19, reprint from T. N. E. C. Hearings, pt. 15, p. 8226, October, 1939.
13. Jake L. Hamon, Dallas, Texas, president of the National Stripper Well Association. Hearing before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 76th Congress, 1940.
14. See note 3, *supra*, p. 610.
15. *Ibid.*
16. *Ibid.*
17. H. B. Fell, on behalf of the Independent Petroleum Association of America, T. N. E. C. Monograph No. 39, p. 19.
18. See note 12, *supra.*
19. *Ibid.*
20. See note 8, *supra.*
21. Otto D. Donnell, president, Ohio Oil Company, Hearings, p. 509, 1934.
22. See note 5, *supra.*
23. *Ibid.*
24. T. P. Thompson, Jr., president, Pennsylvania Grade Crude Oil Association, Bradford, Pennsylvania, Hearings, p. 571, 1934.
25. See note 8, *supra.*
26. See note 2, *supra.*

27. *Ibid.*
28. See note 8, *supra.*
29. Joseph E. Pogue, "Economics of Conservation and Proration in the Petroleum Industry," T. N. E. C. Hearings, pt. 14, p. 7435, 1939.
30. See note 12, *supra.*
31. Glenn E. McLaughlin, assistant professor at Hunter College, and author of portions of the report entitled "Energy Resources and National Policy" (H. Doc. No. 160, 77th Congress, 1st session) prepared by the National Resources Committee, T. N. E. C. Hearings, pt. 14, p. 7435.
32. W. S. Farish, chairman of the board of Standard Oil Company of New Jersey, Hearings, p. 673, 1934.
33. *Ibid.*
34. Jake L. Hamon, Dallas, Texas, president of the National Stripper Well Association, Hearings, p. 1522, 1934.
35. See note 24, *supra.*
36. *Oil and Gas Journal*, July 14, 1938, p. 15.
37. *Ibid.*
38. See note 13, *supra.*
39. See note 1, *supra*, p. 182.
40. See note 8, *supra.*
41. See note 2, *supra*, p. 407.
42. Secretary Ickes, Hearings, p. 181, 1934.
43. *Ibid.*
44. See note 21, *supra.*
45. See note 3, *supra*, p. 610.
46. President of Sun Oil Company, Philadelphia, Pennsylvania, Hearings, p. 386, 1934.
47. Statement before Congressional Oil Investigating Committee at the Oklahoma City Hearing November 12-14, 1934.
48. See note 13, *supra.*
49. Moore, "The Effect of Curtailment on Ultimate Recovery," A.P.I. Release, 1934.
50. *Ibid.*
51. "Economic Aspects of Drilling," *Oil and Gas Journal*, March 17, 1938.
52. See note 29, *supra.*
53. H. B. Fell, Hearings, p. 1845, 1940.
54. See note 21, *supra.*
55. Clyde I. Layton, chairman of Kansas Stripper Well Association, Hearings, p. 1660, 1934.
56. W. T. Holliday, president, Standard Oil Company of Ohio, Hearings, pp. 255, 6, 1934.
57. See note 21, *supra.*
58. See note 29, *supra.*
59. See note 3, *supra*, p. 610.
60. Art. 6049b. § 1, R. S. 1925.
61. Railroad Commisison of Texas vs. Rowan & Nichols Oil Company, 60 S. Ct. 1021, 310 U. S. 573, 84 L. Ed. 1368.
62. T. P. Sanders, *Oil and Gas Journal*, January 30, 1941, p. 192.
63. See note 3, *supra*, p. 610.
64. E. DeGolyer, Dallas, Texas, T. N. E. C. Hearings, pt. 14, p. 7391, 1939.
65. H. B. Fell, T. N. E. C. Hearings, p. 5574, 1939.
66. Parke A. Dickey and Lawrence S. Matteson, "Secondary Recovery Governs Future of Pennsylvania Fields," *Oil and Gas Journal*, December 18, 1941, p. 54.
67. *Ibid.*
68. Champlin Refining Company vs. Corporation Commission, 286 U. S. 210, 52 S. Ct. 559, 74 L. Ed. 1062, 86 A.L.R. 403 (1932).
69. Acts 1931, 1st Called Sess., c. 26, § 4, 5, 14; Rev. St. 1925, arts. 6042, 6046; art. 6029; as amended by acts 1932, 4th Called Sess., c. 2, § 7; Acts of 1932, 4th Called Sess., c. 2, § 3—Acme Refining Co. vs. State, 86 S. W. (2d) 507.
70. The Texas Company vs. Daugherty, 107 Tex. 226, 176 S. W. 717, L.R.A. 1917F 989 (1915).
71. Stephens County vs. Mid-Kansas Oil and Gas Company, 113 Tex. 160, 254 S. W. 290, 29 A.L.R. (1923).
72. Rule 19, part 1; rule 21, part 1.
73. Art. 6008 § 5, R. S. 1925.
74. Vernon's Ann. Civ. St. Tex. art. 6014 et seq.; U. S. C. A. Const. Amend. 14. Railroad Commission of Texas vs. Rowan & Nichols Oil Co., 60 S. Ct. 1021, 310 U. S. 573, 84 L. Ed. 1368, reversing 107 F. 2d 70, affirming Rowan & Nichols Oil Co. vs. Railroad Commission of Texas, 28 F. Supp. 131, certiorari granted Railroad Commission of Texas vs. Rowan & Nichols Oil Co., 60 S. Ct. 613, 309 U. S. 646, 84 L. Ed. 999, rehearing denied 61 S. Ct. 66, 311 U. S. 614, 85 L. Ed. ...., and 61 S. Ct. 167, 311 U. S. 727, 85 L. Ed.
75. Railroad Commission of Texas, Status of the Allowables of Marginal and Proratable Wells on Oil Proration Schedules Effective January 1, 1938.
76. Northcutt Ely, "The Conservation of Oil," 51 Harvard Law Review 1209.
77. People's Petroleum Producers, Inc., vs. Smith 1, F. Supp. 301, Rowan & Nichols Case overruled this case, see note 74, *supra.*
78. *The Petroleum Engineer*, March, 1942, p. 16.

☆ ☆ ☆

COLMONOY SAVES VITAL METALS

The Pug Knives shown above tell a graphic story of the unusual wear resisting qualities of COLMONOY hard-surfacing alloys and overlay metals.

1. New, 24-pound pug knife, made of high alloy steel.
2 and 3. Same type, after only 3 months of service. Worn beyond efficient operation, with over half of blade material worn away.
4 and 5. Same type. Each blade coated with 1½ pounds of COLMONOY No. 6. In constant use for over a year, and still in efficient operation.

COLMONOY alloys are playing an important part in oil production and refining operations in the United States. Pump sleeves, plungers, rings, wash pipes and many other kinds of equipment used in the oil industry are particularly subject to excessive corrosion and abrasion. COLMONOY keeps them on the job.

Write for Full Information

WALL-COLMONOY CORP.

Buhl Building, Detroit, Michigan

Branch Offices
NEW YORK CITY, BLASDELL, N. Y.; CHICAGO; TULSA; WHITTIER, CALIF.
Other branches in Canada

COLMONOY

Hard Surfacing Alloys and Overlay Metals

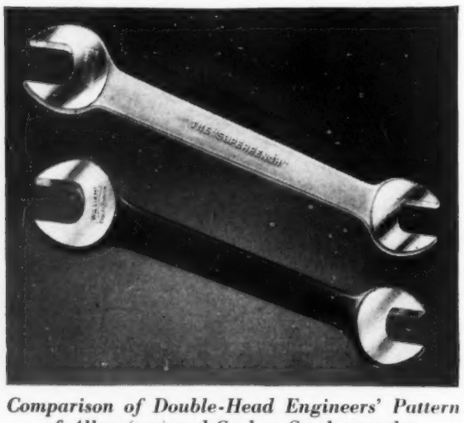
HOW AND WHY
WILLIAMS' TOOLS AID WAR PRODUCTION

J. H. WILLIAMS & CO., *Drop-Forgings and Drop-Forged Tools*, BUFFALO, N. Y.

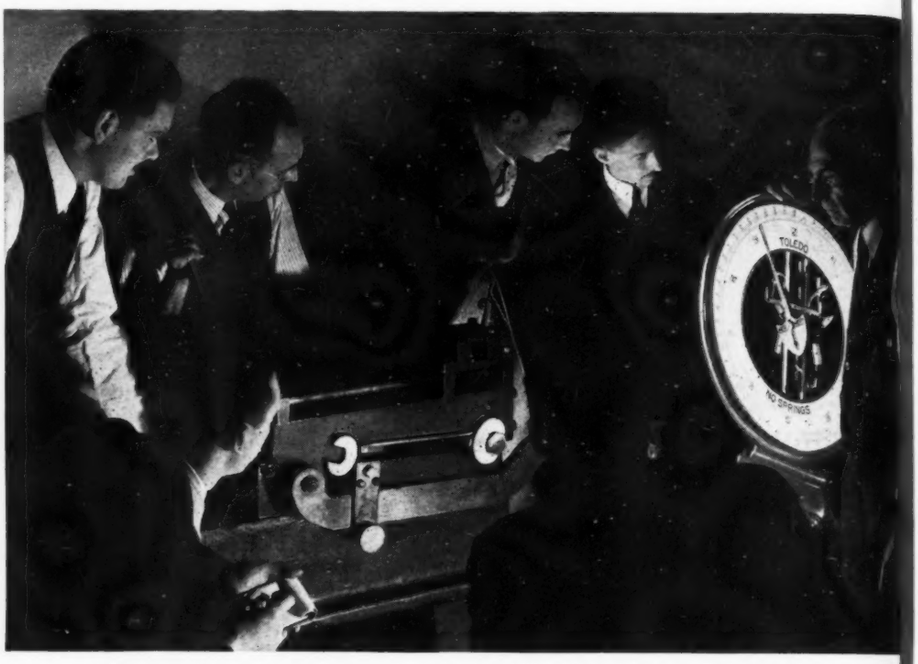
WILLIAMS' "SUPERIOR" (CARBON STEEL) WRENCHES

For some years previous to the war, the popular trend was toward replacement of this type of wrench with alloy steel tools which usually were chrome-plated and more highly finished. Today, however, material shortages and the need for critical economy makes a close examination of the relative merits of carbon and alloy steel wrenches particularly timely. Since we manufacture *both* types, we can present the following facts and figures without bias or prejudice.

Williams' "Superior" Wrenches are forged from carbon steel, specially processed to exacting specifications. These wrenches have been improved to a point where they are substantially twice as strong as the earlier carbon steel wrenches of our own manufacture. Comparative tests demonstrate that they average (throughout all patterns and sizes) 93% as strong as our corresponding alloy steel wrenches. In the popular Double-Head Engineers' pattern.



Comparison of Double-Head Engineers' Pattern of Alloy (top) and Carbon Steel wrenches. Both wrenches have same openings.



Comparative strength tests were made in Williams' Laboratory with every size and type in the carbon and alloy steel wrench lines.

"Superior" (carbon steel) Wrenches are *actually stronger* than the corresponding sizes of alloy wrenches which are of thinner design. Other patterns in the Williams' line are forged from identical dies whether of carbon or alloy steel—thus the *average* shows a slight strength advantage in favor of alloy steel.

Against this slight advantage are the following practical considerations: Alloy steel wrenches cost nearly twice as much as "Superiors"; critical alloys are needed in many items of war production where substitution is highly undesirable; in the Double Head Engineers' pattern, the thicker design of "Superior" Wrenches affords a more comfortable hand grip and a better bearing on the nut; the usual finish supplied on "Superior" Wrenches involves no critical material (such as chrome), since they are finished in baked-on enamel rather than plating.

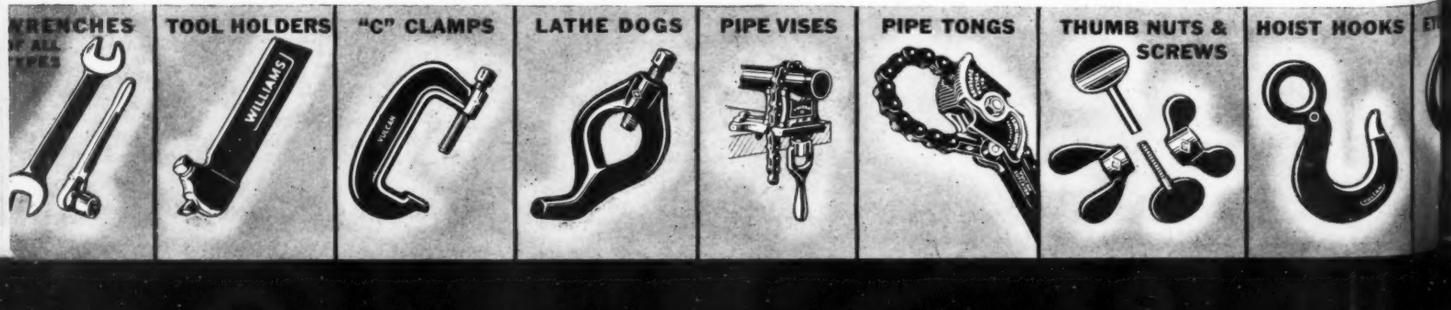
Economize with Carbon Steel Wrenches

In view of today's conditions, we strongly recommend the use of "Superior" (carbon steel) Wrenches wherever possible. For most industrial applications, any advantage in alloy wrenches is negligible. Some types of close-quarters work require the thinner heads available in the Double Head Engineers' pattern of alloy wrenches, thus justifying their higher cost.

An informative booklet, providing comprehensive data on standard wrench types, is available without charge. Write for "How to Select and Use Wrenches."

WILLIAMS
SUPERIOR DROP-FORGED TOOLS
Headquarters
for over half a century for
DROP-FORGINGS and DROP-FORGED TOOLS

Sold by Leading Industrial Distributors Everywhere



Evaluating Petroleum Lubricants

PETROLEUM ENGINEER Exclusive Feature

☆ Judging lubricating oil by performance in user's own equipment is advocated as the best standard of quality

by J. W. Poole

Manager, Research Division, Lion Oil Refining Company

In an article in the May, 1942, issue of The Petroleum Engineer, the author discussed at some length the significance of common specifications for lubricating oils, as well as certain pertinent historical matter. Whereas that article, looking at the past and present, provides a background, we suggest that the reader review it prior to a critical reading of the following, which more or less pertains to the present and future.—EDITOR'S NOTE.

IN THE article "Changing Concepts of Petroleum Lubricants"[1] the subject was handled largely on a basis of "destructive" criticism. Emphasis was placed, almost exclusively, on the inadequacies and fallacies of common methods of evaluating petroleum lubricants. Little attention was given to providing the manufacturer and user of lubricants with more useful methods of scrutiny. To the extent that they are vastly superior to a purely legendary philosophy, such methods do exist; but completely satisfactory tests and infallible specifications are still in the future. The best policy for the present is to keep in mind, and guard against, the limitations of all test methods, both new and old. By maintaining an attitude appropriate thereto it is possible to serve well while waiting for research to develop means of thoroughly sound evaluation.

The present aim is to outline those reliable standards already possessed, particularly stressing the limitations of knowledge so unnecessary troubles may be avoided. The writer believes that the greatest safeguard against avoidable lubrication troubles is a firm resolution to judge an oil, not by what it seems to be but by what it does in one's own equipment.

This article, relating to certain generalities based on carefully observed data, tells not how chemical constitution will affect operation, but what the user of lubricants might expect from certain oil types.

Chemical Constitution and Performance

There is a vast collection of heterogeneous data and facts that bear directly on the relationships between lubricant constituents and service behavior.[2-7] Even when regarded in the most critical light and carefully culled to eliminate the fanciful and inconclusive, the residue still represents a vast and rather staggering store of source material.

J. W. POOLE

prepared for M.I.T. at Phillips Exeter Academy —Specialized in physics, mathematics, and physical chemistry—In research and industry he has devoted himself almost exclusively to petroleum technology and allied fields, and since 1927 has been particularly interested in lubricants and their application—Over a period of about ten years Poole acted in a consulting and advisory capacity for several large organizations associated with the petroleum industry; he has been employed full time in industry for a total of about six years—He first became affiliated with Lion in March, 1939, as assistant refinery manager—In the Fall of 1941 he was appointed manager of the Research Division.

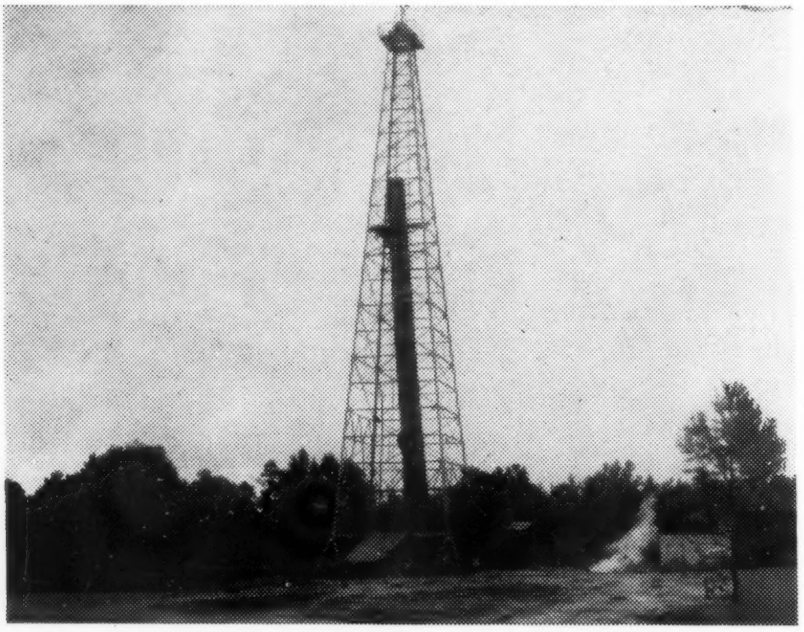
Nevertheless, this imposing accumulation not only appears unsuitable for rigid correlation of chemical constituents and service performance, but presents grounds for doubt whether any humanly possible additions of the same general nature can do more than lead to generalities of limited utility and scope.

In the field of lubrication the research chemist is faced with two monumental obstacles, each of which operates to multiply the complexities of the other. In dealing with hydrocarbons and their derivatives of the molecular size encountered in petroleum lubricants, it is conceivable that problems of countless thousands of distinctly different chemical substances may appear. Perforce it has been assumed that for the purpose of analysis the situation may be properly simplified by dividing these many components into a few categorical groups; thereafter studying the properties of these groups, either individually or in association with other groups or individual substances.[8] The obviously weak point in this pragmatic method is the questionable and almost indeterminable validity of regarding a highly complex and variable mixture as the analog of a pure compound.

The second important obstacle is the almost infinite variability of conditions under which lubrication is performed. In practice, oil is subject to wide ranges and involved sequences of conditions. Temperature, time element, chemical nature of materials of construction, chemical nature and amounts of casual or chance invaders of the system, mechanical type and condition of the equipment, etc., are brought together in such extreme variations of degree and sequence as to stagger the imagination. To sort logically the significant variable from the pointless is a treacherous expedient. To sort them by precise and laborious experiment is an appalling undertaking. A combination of the two methods has appeared to be the most promising recourse. It is the method now generally employed, probably to be continued indefinitely, although there can be no absolute assurance that it is a method leading to greater clarity rather than to worse confusion. The greatest, probably the only great, danger attendant upon its use is a natural inclination to ignore its limitations, which are many.

In application of this compromise method of analysis, the multifarious elements of straight petroleum lubricating oils came to be divided into several semi-arbitrary chemical groupings, whereupon difficulties became quickly apparent. First, although the terms paraffinic, olefinic, naphthenic, aromatic, and resinous are inclusive of all oil constituents, they cannot be made rigidly distinctive. It is not possible to draw sharp categorical distinctions between classes of constitu-

ents when the constituents themselves progress in chemical nature by almost imperceptible increments. Moreover, the distinction between the terms "naphthenic" and "aromatic" has been carelessly disregarded and the terms unnecessarily confused; each, upon occasion, being used to signify that the nature of the material is vaguely antithetical to "paraffinic." Therefore, even at the expense of more precise terminology, it has seemed desirable in this article to concede partially to popular usage, and the ultimate interests of clarity. In lieu of the classifications of fairly recent origin, paraffinicity is here treated as a variable quantity, the different degrees thereof being considered as characterizing a lubricant. By paraffinicity is meant a quality defined by either viscosity index or relationships between gravity and viscosity. Likewise, it may be defined by unsulphonated residue. In general these definitions will be in approximate, but not exact, accord. For purposes of mental orientation the terms "paraffinic oil" and "naphthenic (or more properly "aromatic") oils can be considered as respectively referring to oils of 90 or greater viscosity index and 20 or lower viscosity index.



FOR DRILLING
and other Oil Field Operations
Use Natural Gas

FOR DRILLING . . . Natural Gas presents no fuel storage problem. It is always ready and its ease of handling promotes maximum efficiency at the rig.

FOR REPRESSURING AND LEASE OPERATIONS . . . Natural Gas is economical and dependable.

We will welcome an opportunity to serve you in your drilling or other oil field operations in the Gulf South. A phone call or letter to any of our offices* or employes will receive prompt attention.

* TEXAS: Beaumont, Dallas, Fort Worth, Houston, Longview, San Antonio and Wichita Falls.
LOUISIANA: Baton Rouge, Iowa, Monroe and Shreveport.
MISSISSIPPI, ALABAMA and FLORIDA: Jackson, Mississippi.

UNITED GAS PIPE LINE COMPANY
AND ASSOCIATED COMPANIES

DEPENDABLE NATURAL GAS SERVICE DOESNT JUST HAPPEN

Paraffinic Oils

In the best terms available, consider how different types of oil may be expected to perform in service. In general, highly paraffinic oils give the appearance of great stability in service; they darken very slowly and samples analyzid by common methods show them to be very resistant to substantial chemical alteration, both being circumstances logically to be desired. They do, however, form lacquer, which eventually leads to serious engine deposits. In general, the deposits from paraffinic oils are very hard and tenacious.[9] A serious result of hard deposits is that form of scratching and gouging known as piston crown scuffing, frequently found only when such oils are used to lubricate aluminum pistons.

Moreover, members of the General Motors' Research Laboratories recently discovered a very serious result of long drain periods, for highly paraffinic oils.[10] In a long and careful study it was observed that the stability of such oils was possibly more apparent than real; that actually they produced heavy resinous materials, which so long as fresh oil was not added in quantity remained dissolved in the parent medium, but when relatively large amounts of fresh highly paraffinic oil—even when identical with that from which the resinous materials were formed—were mixed therewith the result was almost immediate precipitation of a thick gummy mass. This in turn when picked up by the oil pump would promptly cause heavy deposits and subsequent sticking of vital engine parts, even to the extent of completely preventing movement thereof. Such conditions were curable only by a complete engine overhaul. Although the investigators repeatedly noted these facts about "premium grade" paraffinic oils, no such circumstance was found to occur when using other than highly paraffinic oil; in fact, such precipitation did not occur when naphthenic oil was mixed with the used paraffinic lubricant.

On the credit side of the ledger it was found that highly paraffinic oils of high viscosity index are much less likely to become so stiff on a suddenly cold day as to prevent the starting of a cold engine.* Moreover, they are distinctly less prone to form cold driving "moisture sludge", which is the winter "bug-a-boo" of many car owners and lubricant distributors. At the present time it appears that high viscosity index oils offer the best overall compromise with what seem to be mutually incompatible requirements of winter crankcase problems.

*It remains to be conclusively demonstrated, however, that high initial viscosity is the sole factor in difficult starting.

Non-Paraffinic Oils

Just as the highly paraffinic oils have their deficiencies, so do non-paraffinic, low viscosity index oils have theirs, which although possibly less spectacular are undeniably serious. In general, low viscosity index oils are sludge formers. At low temperatures they all too readily form "moisture sludge". At high temperatures their use may result in heavy deposits of "high temperature sludge."

To be sure, sludge *per se* may be no more than a nuisance, but in large amounts it greatly shortens filter life and we have very good cause to regard any and all sludge as a potential source of engine deposits. Furthermore, many a user of low viscosity index oil has found his battery unable to cope with oil drag on a sub-zero morning, when some high viscosity index oil of the same SAE grade would have permitted easy starting.

There are certain very real advantages to be derived from these so-called "naphthenic" oils, however; first, they are typically just as competent—sometimes better—lubricating agents as are paraffinic oils, and they do not cause the trouble discovered by General Motors engineers. Moreover, although they appear to form deposits considerably more readily than do paraffinic oils these deposits are not so likely to comprise "lacquer." The "carbon" is much softer and very unlikely to result in crown scuffing of soft metal pistons. Finally, they rarely prove corrosive to high-duty alloy bearings. Corrosive tendencies cannot be determined merely by knowing the oil type; but the overwhelming majority of highly corrosive oils have also been paraffinic.

In addition to the good and bad features enumerated, each type has minor and less positively associated strong and weak points; also, different SAE grade oils of one type may be in some respects better or worse than each other and to a notable degree. If oils intermediate of "highly paraffinic" and "non-paraffinic," were included in this discussion it would be possible to continue the dissertation almost without end.

For the present purposes it will serve to drop "intermediate" type oils with a brief warning: Although it is possible to devise certain compromises between the two extremes, there are no assurances, except those provided by service, that intermediate type oils will have intermediate propensities. In fact, it seems at least as easy to produce an oil that combines the deficiencies of each type, as to produce one that minimizes the weak points while taking substantial advantage of the desirable features. Furthermore, the specific service involved usually emphasizes the importance of these several propensities.

It is also important to bear in mind that neither an artificial blend of highly paraffinic oil with highly naphthenic oil nor a naturally occurring equivalent may be expected to be "intermediate" in its service characteristics.

Possibly the most valuable knowledge possessed relative to crankcase chemistry is that the reactions are so multi-varient and so complexly interdependent as to be practically unpredictable in light of present knowledge. Seemingly the chemical reactions that occur during service can lead to a variety of new chemical conditions that may be either useful or detrimental, depending on the chemical nature of the reactants, their ratios each to others, their concentrations, temperatures, nature of the metallic surroundings and of chance invaders, the degree to which reactions have occurred, etc.

It is known, for example, that oxidation of some petroleum substances will be productive of auto accelerators of this reaction, but in others auto retardants will be formed. Also, these same reaction products may be useful or detrimental from other aspects whereas

"COYNCO"

in

WAR EMERGENCY PROCESS EQUIPMENT

Atmospheric Stratube Sections
Submerged Stratube Sections
Shell and Tube Heat Exchangers

SERVICES

Heat Exchanger Reconditioning

All the latest development in Shell and Tube, Submerged and Atmospheric practice are assured our customers by "Coynco" engineering. We invite your inquiries concerning heat exchanger problems.

Distributors:

DANIEL ORIFICE FITTING CO.
M. H. DETRICK CO. (Ins. Div.)
EASTERN ENGINEERING CO.
YARNALL-WARING CO.
"COYNCO" STEAM SPECIALTIES
MANNING, MAXWELL & MOORE, INC.
H. O. TRERICE COMPANY
READING-PRATT & CADY CO.
KROPP FORGE COMPANY
"COYNCO" OIL SPECIALTIES

"We Cover the Mid-Continent"

•

We are proud to announce that the entire facilities of our plant and personnel are directed to "all-out" effort in this emergency.

Joseph A. Coy Co., Inc.
3515 Dawson Road Phone 3-9196
TULSA, OKLAHOMA

the balance for good or evil may be entirely different for different concentration ranges. The addition of certain naphthenic or aromatic material to a paraffinic base stock in certain proportions can produce blends distinctly more durable in service; other blends of the same base materials can have an absolutely contrary effect. From several independent pieces of work it has become apparent that maximum oil stability is not to be attained through high oil "purity" but unquestionably is a function of the ratio of paraffinic and non-paraffinic materials. The must durable oils apparently comprise material percentages of "paraffinic", "naphthenic", and "aromatic" groups. Doubtless we shall find that other adversely regarded constituents of petroleum are actually useful lube oil components. The proved value of sulphur derivatives of hydrocarbons is in fact such an example. All of which leads back to the main theme of this discussion:

Specifications based on characteristics rapidly determinable in the laboratory are completely unreliable guides to how well an oil will do its work. The conventional standards still generally used as criteria are not indicative of the quality of an oil, a fact that for automotive service should be given especial emphasis.[11]

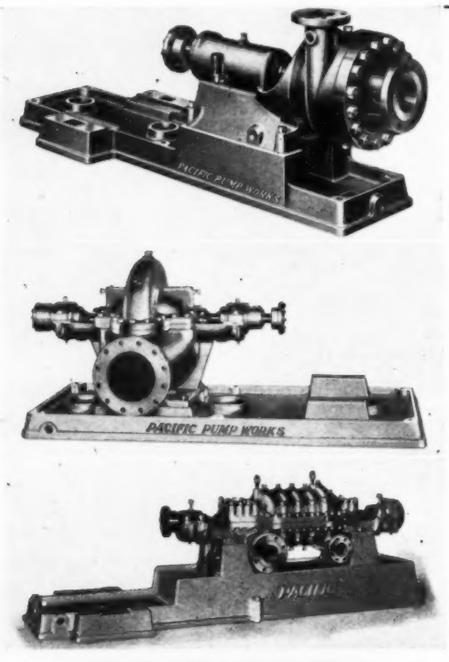
So far, tests in engines under either actual conditions or controlled conditions designed to simulate service, have been shown to be the only reliable criteria.[12, 13] They are infinitely superior to any alternative as yet devised, but admittedly, even such tests leave much to be desired; they are time-consuming and expensive, yet, today, owners of Diesel equipment manufactured by such concerns as Caterpillar and General Motors—who require that "approved oils" be proved—have far more assurance of being able to buy oil that will give them satisfactory service than do those who purchase under the influence of prejudice and tradition.

So far the most publicized work has been with Diesel lubricants, and although there is excellent reason to believe that a superior Diesel lubricant is also superior for hard-driven automobiles, to assume so would be to fall into the same basic error of using logic to decide what should constitute a good oil. Having made a beginning toward converting lubrication from the field of philosophy to that of science, it might be well to maintain the trend. What is needed above all else is to educate those who distribute and use oil, plus the technologists who have fallen behind the times, to the effect that not only the final but the only defensible criterion of lubricants is performance.

References.

1. J. W. Poole, *The Petroleum Engineer 13*, 140 (1942)
2. Hermann Zorn, *Angew. Chem. 50*, 791-7 (1937)
3. Hilliger, *Oberflachentech 10*, 221 (1933)
4. Frederick D. Rossini, *Refiner and Natural Gasoline Mfr. 15*, 499-506 (1936)
5. W. B. Hardy, *Dept. Science Ind. Research*, Lubrication Research Tech. Paper No. 1, 1-66 (1930)
6. F. W. Sullivan, Jr., V. Voorhees, P. T. Oak, and D. P. Barnard, *J. Soc. Automotive Engineers 29*, 40-4 (1931)
7. C. M. Larson, W. G. Ainsley, and M. Fairlie, *Oil and Gas J. 34*, No. 39, 24-5 (1936)
8. M. R. Fenske, C. E. Stevenson, N. D. Lawson, G. Herbolsheimer, and E. F. Koch, *Ind. Eng. Chem. 33*, 516-24 (1941)
9. H. N. Bassett, *Auto Eng. 28*, 31-2 (1938)
10. H. R. Wolf, Nat. Fuels and Lubricants Meeting S.A.E., Tulsa, November 7, 1940.
11. A. T. Wilford, *J. Inst. Petroleum 25*, 607-22 (1939)
12. C. G. A. Rosen, *Proc. Am. Petroleum Inst.*, 7th Mid-Year Meeting, Sect. III, *18*, 74-83 (1937)
13. A. O. Willey and C. F. Prutton, Summer Meeting S.A.E., White Sulphur Springs, W. Va., June, 1940.

——— ☆ ☆ ☆ ———



WRITE FOR BULLETINS

FOR **VITAL** PUMPING SERVICES

. . . . . *Specify* **PACIFIC**

Pacific Pump Works has consistently anticipated the Pump requirements of the oil industry. Pacific Centrifugal Pumps were the first to meet successfully the pumping condition of 2000 pounds pressure for hot oil. Pacific pioneered the vertical suction and discharge pumps for dependable handling of light oils, propanes, butanes, emulsions. Pacific Pumps perform consistently and economically in oil refineries and pipe line pumping plants the world over because Pacific pretested design and engineering assures the selection of the right pump for the job. The dependability of Pacific Plunger Pumps lift oil economically even under the most difficult conditions. A reflection of the reliability of Pacific Pump performance is the record of steadily increasing installations throughout the nation. Bulletins available upon request.

PACIFIC PUMP WORKS

Executive Offices and Plant:
HUNTINGTON PARK, CALIF.
Offices in principal cities in the United States

Subsidiary
MID-CONTINENT PUMP SUPPLY CO.
TULSA, OKLA.

PACIFIC PUMP WORKS PACIFIC HUNTINGTON PARK CALIF

PACIFIC *Engineered* **PUMPS**

Adaptation of the Centrifugal Pump to Refinery Use

PETROLEUM ENGINEER Exclusive Feature

☆ Refinery operator must know and understand pump design and features to obtain efficient operation

by R. G. Lovell

Development Engineer, Hancock Oil Company of California

BEFORE ultimate service may be obtained from a centrifugal pump there must be an understanding of the principal features of design and knowledge of how the manufacturer has endeavored to coördinate these with the wide range of operating demands that a refinery operator is likely to make upon the pump. The greatest handicap this type of pump has had to overcome in attaining its present popularity arises from failure on the part of many refinery men to understand its working principle, and failure to apply the knowledge. In the early development of the centrifugal pump its use was thought to be limited to those applications where the head and volume duty were constant and where the liquid to be handled was low in viscosity and not volatile. No claims were made of an overall efficiency comparable with the displacement pump. As time went on improvements were made such as the closed impeller, more careful calculation of the effects of inlet and outlet orifice shapes and sizes, and, most important of all, the shape of the impeller vanes. The latter made the centrifugal pump suitable for pumping higher viscosity oils. Much trouble was also experienced with the earlier centrifugals from cavitation and, obviously, it came to be considered that a flooded suction must be provided else the pump would not give satisfactory service. Improvements in casing and packing box design disposed of some of this difficulty but it became obvious that most of the trouble was due to the manner in which the suction connections had been made. Despite the convincing evidence that this was the case, many continued to have and to exercise a prejudice against the centrifugal pump.

The only thing required to erase this prejudice is a clear conception of the fact that a centrifugal pump operates wholly by imparting velocity to the liquid and that the casing of the pump transforms this kinetic energy to pressure energy as the liquid flows through. In general, this is accomplished by making all passages through the vanes and case to conform as nearly as possible to the directions the liquid would most naturally follow. There must be, of course, one right-angle turn, as no matter how or where the suction is placed, the liquid must enter axially and leave radially to the impeller.

R. G. LOVELL

received his academic training in New York and served several of the larger mining and milling companies of New Mexico, Arizona, and the Republic of Mexico—Was employed as power engineer and master mechanic from 1908 to 1917, then served in the engineering corps until 1919—After the war he became affiliated with the oil refining industry, first with Standard Oil Company of California as refinery construction engineer and later with a foreign company—He was made assistant to the chief engineer of Pan American Petroleum and Transport Company for the construction of their California processing properties—He is now development engineer for The Hancock Oil Company of California.

The end suction type pump is perhaps the most efficient hydraulically, but the entire thrust load caused by change of direction of the liquid must be carried by a mechanical bearing, a failure of which can cause damage to the pump. In general, it may be stated that the end suction type is ordinarily used for the higher heads that are within the range of a single stage, up to 500 ft.

The double suction type requires but slight attention to thrust load, as the liquid enters from both sides of the impeller. Particular care should be taken to provide suction conditions that permit full advantage to be taken of this feature; that is, care should be taken that the liquid is free from turbulence as it enters the pump, such as that caused by restricted area or a sharp turn near the pump. When the double suction pump is driven by an induction motor the tendency of the electric current to hold the rotor to center helps further to attain the desired condition. Also, the rotor should be centered between its bearings when doweling the units into position. The horizontally split case made possible by the double suction design contributes to the accessibility of the unit. As the pump load is centered between packing boxes and between bearings, packing and bearing troubles are reduced, as well as vibration.

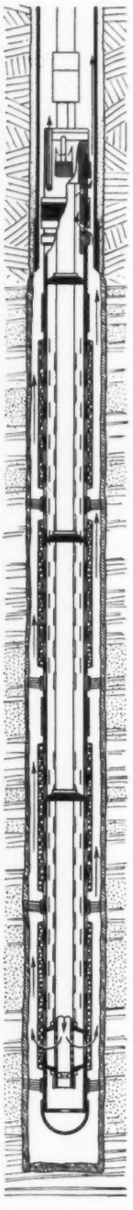
Suction Limitations

Suction conditions are among the important factors affecting the operation of a centrifugal pump. Abnormally high suction lifts usually cause serious reduction in the capacity and efficiency of the pump and often lead to serious trouble from vibration and cavitation. It has been pointed out many times that these suction conditions are very largely within the control of the operator by the manner in which the suction connections are made, and this will be discussed later in this article. How are suction conditions provided for in the design of the pump itself? Standard centrifugal pump guarantees are made, unless otherwise specified, upon not more than 15 ft. total dynamic suction lift when pumping the required capacity of water at a temperature not to exceed 85°F. at sea level.

Specific Speed

The effect of suction lift on a centrifugal pump is related to its head, capacity, and speed. The relationship of these factors for design purposes is

MAXIMUM PRODUCTION
Assured by Mud Removal with B & W Completion Method



THIS METHOD, illustrated by the diagrams at left and right, shows how positive mud removal is accomplished when setting production liners—either gravel-packed or perforated. The essential part of the process is the use of . . .

B and W, Inc.

WALL CLEANING GUIDES

One trip into the hole lands liner, removes mud behind liner, washes gravel pack or perforations and prepares well for production.

Bailing and Swabbing Greatly Reduced . . .

No costly bailing period for pumping wells—and a very short swabbing period for flowing wells. In one recent case a well was brought in by the B and W Completion Method after only seven hours' swabbing, while an offset well using conventional methods required over four days.

Wells "Clean Up" Quickly . . .

There is a quick change from wash fluid to clean, mud-free oil when the B and W Completion method is used.

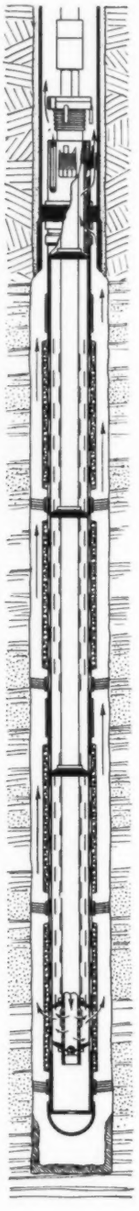
WRITE OR PHONE FOR INFORMATION . . .

Contact your nearest B and W Office for full details on this time- and money-saving completion method.

◆ ◆ ◆

Left: Showing mud removal behind liner.

Right: Liner set and washing gravel pack or perforations.



BRUCE BARKIS — B and W, Inc. — KENNETH WRIGHT

Well Completion Specialists

Makers of

B & W WALL CLEANING GUIDES

Gulf Coast and Foreign Distributors of

NELSON PRE-PACKED GRAVEL LINERS • WILLIS ROTARY CHOKES

WEST COAST
3545 CEDAR AVE.
L. B. 4-8366
LONG BEACH
CALIFORNIA

GULF COAST
1105 Commerce Bldg.
PRESTON 9783
HOUSTON
TEXAS

expressed in the specific speed. The specific speed of an impeller is the r.p.m. at which a geometrically similar impeller would run if it were of such size as to discharge 1 gal. per min. against a 1-ft. head.

The formula is as follows:

$$\text{Specific speed, } N_s = \frac{\sqrt{\text{g.p.m.}} \times \text{r.p.m.}}{H^{3/4}}$$

H = head per stage, ft.

The specific speed of an impeller is an index to its type. It is used when designing impellers to meet different conditions of head, capacity, and speed. Impellers for high heads usually have low specific speeds and impellers for low heads usually have high specific speeds. It has been found very valuable as a constant in determining maximum suction lifts without cavitation occurring, for different conditions of capacity, head, and speed.

It has been found that for a given head and capacity a pump of low speed and, consequently, low specific speed will operate safely with a greater suction lift than one of a higher speed. If the suction lift is very high (greater than 15 ft.) it is often necessary to use a slower speed and consequently a larger pump, whereas if the suction lift is low, or there is a positive head on the suction, the speed may be increased and a smaller and less expensive pump may be used.

Specific Speed Limitation

As increased speeds without proper suction conditions often cause serious trouble from cavitation, vibration, and noise, centrifugal pump manufacturers, through their central body, the Hydraulic Institute, have caused to be plotted the specific speed curves (see Fig. 1) that represent the upper limits of specific speeds in respect to capacity, speed, head, and suction lift (taken at the pump suction flange and referred to as the center line of the pump) to which centrifugals may be applied with assurance of freedom from cavitation, etc. These curves apply to single-stage pumps of the double-suction type. Similar curves restricting specific speeds for other types of pumps are in preparation and will be released from time to time by the Hydraulic Institute, 90 West Street, New York City. At this point the writer wishes to acknowledge the very valuable aid he has had from the publications of the Hydraulic Institute, from which he has drawn freely. This organization is concerned entirely with establishing technically sound standards of design for its sub-

scribing companies, the pump manufacturers. The results of its work are made available to interested persons at nominal prices and one may depend upon these results, not only because they are accurate and authoritative, but because they have no taint of selfish exploitation.

Installing Centrifugal Pumps

Many of the instructions for installing centrifugal pumps seem to be extremely rudimentary. The writer learned the force of this, not from contact with the highly-trained mechanics of our own country, but from his years of experience as a master mechanic in the mines and milling plants of Mexico where the men were entirely without training other than that gained from actual experience; they seemed to know instinctively that they must align carefully both pump and motor before doweling into position, and that provision must be made to relieve piping strains from the pump. To impress upon them the value of taking certain precautions in making suction connections to a centrifugal pump was more difficult, however, because it required the exercise of imagination to understand it.

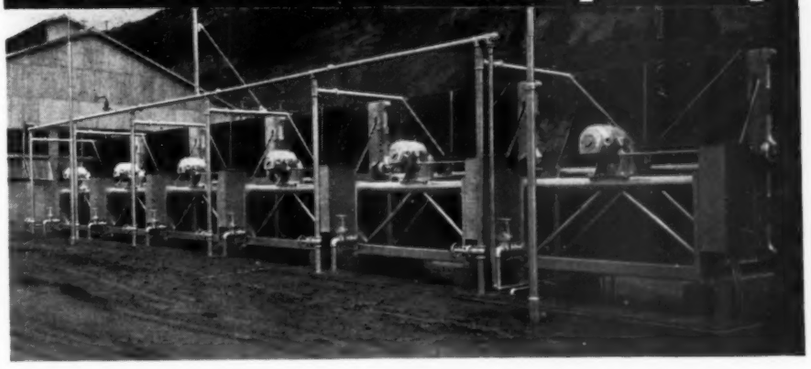
Discharge Piping

A check valve and a gate valve or cock should be installed in the discharge line from a centrifugal pump. The check valve, placed between the pump and the gate valve, is to protect the pump from excessive pressure and to prevent the liquid running back through the pump in case of failure of the driving unit. The gate valve is used in priming and starting and when the pump is to be shut down. It is advisable to close the gate valve before stopping the pump when a foot valve or check valve is installed to prevent water hammer. This is especially important when the pump is operated against a high static head. If reducers are used on the discharge side to increase the size of discharge piping, they should be placed between the check valve and pump.

Suction Piping

The suction should slope continuously upward to the pump and any nearly horizontal sections of the line must have a gradual rise to the pump. If other piping is in the way, the suction line should be laid under it. Any high point in the pipe will become filled with air or vapor and thus prevent proper operation of the pump. A straight taper reducer should not be

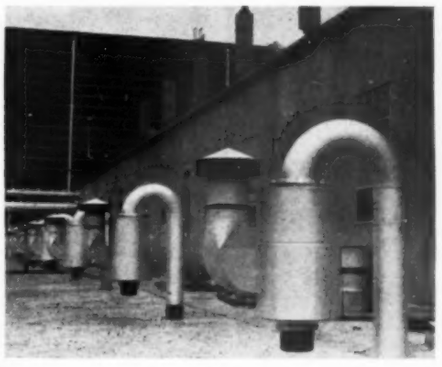
RINCON FIELD ENGINES COOLED by Young



The above installation of YOUNG Jacket Water Coolers at Rincon Field, Ventura, California, demonstrates the ability of YOUNG-engineered cooling units to fit ALL requirements of a job and at the same time cut power costs 50% and more. Six YOUNG units cool four 600 HP Diesel-convertible engines direct connected to 400 KW generators. Eighty-three inch propeller fans in the units are driven by 15 HP 2-speed gear motors. Of unusual interest are thermostatic controls which switch the motor on and off, and from No. 2 to No. 1 speeds with every change of 4 degrees in the temperature of the jacket water. YOUNG engineers can solve your cooling problems with equal effectiveness. Consult them today.

YOUNG RADIATOR COMPANY, Dept. 282-G, Racine, Wisconsin, U.S.A.
Mid-Continent Distributor: THE HAPPY COMPANY, Tulsa, Oklahoma
Pacific Coast Distributor: A. R. FLOURNOY, Bell, California

Young HEAT TRANSFER PRODUCTS
OIL COOLERS • GAS, GASOLINE, DIESEL ENGINE COOLING RADIATORS • INTERCOOLERS • HEAT EXCHANGERS • ENGINE JACKET WATER COOLERS • UNIT HEATERS • CONVECTORS • CONDENSORS • EVAPORATORS • AIR CONDITIONING UNITS • HEATING COILS • COOLING COILS
Young SERVICE



DUST AND GRIT CAN SABOTAGE YOUR ENGINE

Let VORTOX keep them out

Today, as never before, you must protect what you have. Most oil field engines must last for the duration and need the best protection you can give them.

Vortox Air Cleaners provide protection for your engine where it is most needed — on cylinder walls, pistons, valves, and other vital parts—by keeping dust and grit out.

Nothing but dust-free air can get into the combustion chamber when you use a Vortox Cleaner. *Three* cleanings see to that. The whirling action of the air first throws out the larger dust particles . . . then a cyclonic oil spray and the oil washed filter give the air a second and third cleansing. A Vortox Air Cleaner is simple to clean . . . you remove the dirty oil and sediment and refill with clean oil. There are no bulky parts to clean, wear out and require replacement.

Vortox Cleaners are available for engines developing from ½ to 3500 horsepower—using gas, gasoline, or Diesel fuel. You'll find a Vortox standard equipment on most popular engine makes. Let Vortox Cleaners cut your replacement costs.

VORTOX MANUFACTURING CO. • CLAREMONT, CALIFORNIA

VORTOX OIL TYPE SELF-WASHING AIR CLEANER

CLEAN LINES for LONG LIFE

This steel encased wiper with rubber filler strips the oil and mud completely. The housing is easy to open and is equipped with hold down chain and quick operating safety releases. Spirally-wound rubber refill is replaceable. This is Style B. Give it a trial.

PATTERSON-BALLAGH

WIRE LINE WIPER

Other Equipment-Saving Products by Patterson-Ballagh:

Drill Pipe & Casing Protectors

•

Pipe & Tubing Wipers

•

Sucker Rod Wipers

•

Tubing Protectors

•

Wire Line Guides

See Composite Catalog

PATTERSON-BALLAGH CORPORATION

Los Angeles Houston
New York City

used in a horizontally-inclined suction line, as it forms an air pocket in the top of the reducer and the pipe. An eccentric reducer should be used instead. If a pocket is left in the suction pipe when the pump is primed, the pump may start and pump properly for a time, but it is probable that a quantity of vapor (steam or air) will be drawn from the pocket upward into the pump, causing a loss of prime. This is especially true when the pump is primed by use of a foot valve; but even when it is primed by steam ejector or vacuum pump, a small quantity of air or vapor remains in the pocket and this is added to, both from vapor in the liquid that is released by the partial vacuum in the suction pipe, and from air admitted through minute leaks in the pipe connections that ordinarily would not cause trouble.

Small pockets that may cause trouble are found in the top of any gate valves installed vertically in the suction line. Gate valves in the suction line should be laid so that their stems are horizontal.

Check Valves in the Suction

Check valves ordinarily should have no place in the suction line, although they are of advantage and are sometimes used in series-parallel operation to reduce the number of valves to be operated when changing from series to parallel operation. The pump must not be throttled by the use of a valve on the suction side.

Elbow on Suction

Suction piping for double suction pumps should not be installed with an elbow close to the suction nozzle of the pump except when this elbow is in a vertical position; that is, an elbow looking either straight up or straight down is permissible, but one entering at another angle should not be used. There is always turbulence in an elbow that causes an uneven flow and when it is installed in any but a vertical position this unequal flow causes more liquid to enter one side of the runner than can enter the other side, thus causing a reduction in capacity and efficiency and a thrust that will heat the thrust bearing and possibly be of sufficient magnitude to cause rapid wear or failure of the thrust bearing. It must be remembered that the double-suction pump is not expected to have as much end thrust as the end-suction type and, therefore, the thrust bearing is sometimes not designed for heavy duty.

Foot Valve

When the suction is not especially high it is frequently advisable to install a foot valve to facilitate priming. Foot valves should not be used when the pump is operating against a high static head, unless the check valve on the discharge side is designed to take care of the shock load resulting from a power failure. The foot valve should be of the flap type having a clear passage for the liquid of at least the same area as that of the suction pipe. If a screen also is used it should have enough openings to keep the flow through it at less than 2 ft. per sec. even when partly obstructed.

Oil-Lubricated Sleeve Bearings

Oil-lubricated sleeve bearings should be kept filled with a neutral mineral oil of about 200 Saybolt Seconds Universal viscosity. This is about a S.A.E. 10 grade. It is important that this be a neutral oil, which is more stable to oxidation than a heavier one that might be compounded with some percentage of bright stock. Lubricating oils from paraffinic or from mixed-base crudes are considered more resistant to oxidation than those from naphthenic crudes. Although the temperature and other conditions in a pump bearing are not so severe as in an automobile engine, oxidation does occur in the pump or motor bearings and its results are insidious, because they are not readily apparent. Oxi-

dation produces certain fatty acids that are likely to cause trouble from corrosion of shaft and/or bearings.

Ball Bearings

The importance of proper lubrication of ball bearings in pumps cannot be overemphasized. The use of ball bearings made it practicable to take advantage of the efficiency and lower cost of the two-pole induction motor as a driving element for a centrifugal pump; but the idea was retarded by the tendency on the part of operators to regard the lubrication of ball bearings in the same light as that of sleeve bearings. As a result, many bearing failures occurred, most of which were traceable to improper lubrication.

Prerequisite to an intelligent consideration of lubricants for ball bearings, it should be recognized that:

1. The total friction load upon a bearing is a combined function of the weight of the borne member and its speed.

2. The load carried by each unit of bearing area is the result of dividing the total load in lb. by the number of sq. in. of bearing area.

3. That in any except a perfectly balanced high-speed machine the total load is borne almost entirely by the lower half of a sleeve bearing.

4. Despite all reasons hereinbefore given, there comes a practical limit to the load that each of the small areas of a ball bearing can safely withstand. When this limit has been reached, the sleeve bearing is the logical answer. The use of roller bearings in an endeavor to strike a compromise has not been generally successful.

The duty required of a lubricant in a ball bearing is almost entirely the reduction of rolling friction and distribution of the heat caused by the weight of the shaft to the larger areas of the housing, where it can be dissipated more rapidly by radiation to the surrounding air. The best lubricant, therefore, is a light neutral mineral oil.

Need Protection for Overhead Welding?

Few helmets ... regardless of protection ... offer greater comfort than the Walker Welding Helmet. Protection is provided for complete head and neck, with no possibility of backflash. Other models include fibre helmets, goggles, etc., all described in condensed folder. 1B-7

Many Other Models Described

E. D. BULLARD COMPANY
275 Eighth Street
San Francisco, California.
Everything BULLARD in Safety

Send me free condensed folder describing welders' protective equipment designed to meet today's specialized needs.

Name _____

Address _____

City _____ *State* _____ PE

NATIONWIDE SALES AND STOCKS

INDEPENDENCE

from boiler scale and corrosion; past—present—future, through the use of

SAND-BANUM

Safe—Certain—Economical despite water or operating conditions.

"The entirely Different Boiler and Engine Treatment"

Proofs and Detailed Data sent on request.

AMERICAN SAND-BANUM COMPANY, Inc.

9 Rockefeller Plaza New York City

Changed Concept of Lubrication

A different concept of the duty of a lubricant in the modern high-speed bearing is offered for the consideration of the reader. This changed concept came as a result of experience with the power plant of an automobile. The unit with which this experience was had, the "loping laboratory," was pictured and described in a previous article.[1] That article, however, dealt only with one of the developments in fuels for automotive apparatus.

[1] "Blending to Improve Refinery Products," by R. G. Lovell, *The Petroleum Engineer*, February, 1942.

Why THE INDUSTRY'S LEADING CENTRIFUGE?

BECAUSE: Heavy duty, ruggedly constructed and extremely simple in design ... Gets quick, accurate results ... Produces required speed with less effort ... Cranks and heads of 100 CC and 15 CC size machines interchangeable ... Meets *A.S.T.M. Standard Method D-96 and A.P.I. Code No. 25* requirements.

W·H·CURTIN & CO. Inc

HOUSTON U.S.A. TEXAS

From the research work with this car doubt arose regarding the theory of a physical film of lubricant between bearing surfaces, which are but 0.0015 in. apart, for it does not coincide with knowledge of the physical characteristics of a mineral lubricating oil of about 0.887 specific gravity. When the old theory is discarded, a new one must be presented to replace it. The writer proposes that consideration be given to the thought that this film of lubricant be considered as of molecular proportions rather than physical. This concept can be justified by the discussion that has been offered of the functions of ball bearings in high-speed centrifugal pumps.

An endeavor was made several years ago to use ball or roller bearings in the shackle bolts of automotive equipment, but that idea was abandoned. The ostensible reason for the failure was the difficulty of excluding road dust from the bearings. This was true, of course, but the real reason was a matter of fundamentals. There was practically no rolling friction. The load was partly straight compression. These added up to one duty; that of distributing a weight over a bearing surface. The ball or roller bearings simply did not have sufficient contact area in half of the bearing to support this load, despite

Rubber Products

AVAILABLE IN STOCK

FOR

Immediate Shipment

V-BELTS

Multiple Drive Belts—Matched Sets

PARTIAL LIST OF SIZES

Belt Sizes E WIDTH	Belt Sizes C WIDTH	Belt Sizes B WIDTH	Belt Sizes A WIDTH
E-180	C-51	B-42	A-26
E-195	C-60	B-46	A-31
E-210	C-68	B-51	A-35
E-240	C-75	B-55	A-38
E-270	C-81	B-60	A-42
E-300	C-85	B-68	A-46
E-330	C-90	B-75	A-51
E-360	C-96	B-81	A-60
D WIDTH	C-105	B-85	A-68
D-120	C-112	B-90	A-75
D-128	C-120	B-97	A-80
D-144	C-128	B-105	A-85
D-158	C-144	B-112	A-90
D-162	C-158	B-120	A-96
D-173	C-162	B-128	A-105
D-180	C-173	B-144	A-112
D-195	C-180	B-158	A-120
D-210	C-195	B-173	A-128
D-240	C-210	B-180	
D-270	C-240	B-195	
D-300	C-270	B-210	
D-330	C-300	B-240	
D-360	C-330	B-270	
	C-360	B-300	

RUBBER BELTING

HEAVY DUTY—SILVER DUCK—SQUARE EDGE—A.P.I. SPECIFICATIONS

Furnished in All Required Lengths

Width Ply	Width Ply
8" x 6	14" x 6
10" x 6	16" x 6
12" x 6	18" x 6

(Other Sizes Available)

RUBBER HOSE

All Types and Sizes for Use on OXY-ACETYLENE WELDING, AIR COMPRESSORS, STEAM, OIL, SUCTION, WATER, FIRE, PAINT, ETC.

FURNISH DETAILS OF YOUR REQUIREMENTS ... PROMPT QUOTATIONS ... IMMEDIATE SHIPMENTS

CARLYLE RUBBER CO. Inc.

64 Park Place New York, N. Y.

"BUY MORE WAR BONDS"

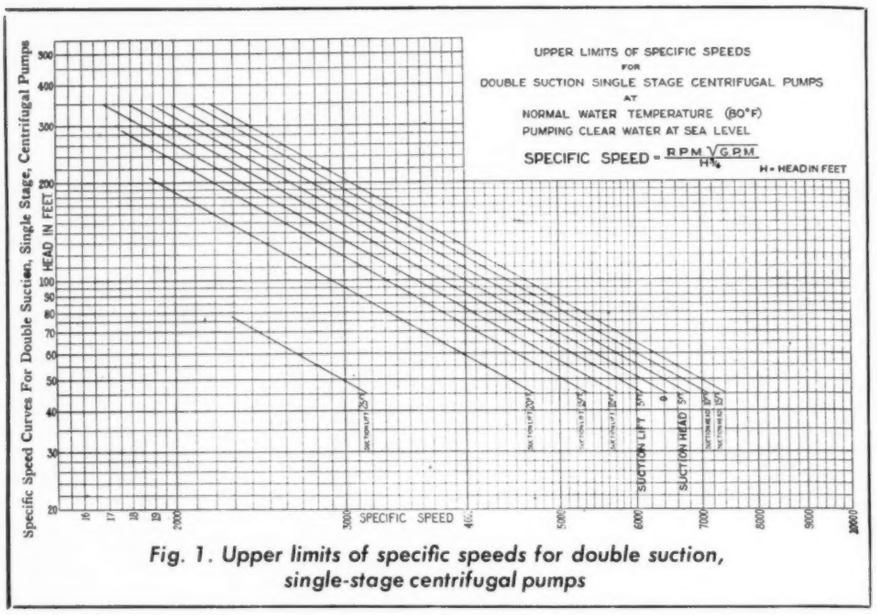

UPPER LIMITS OF SPECIFIC SPEEDS
FOR
DOUBLE SUCTION SINGLE STAGE CENTRIFUGAL PUMPS
AT
NORMAL WATER TEMPERATURE (80°F)
PUMPING CLEAR WATER AT SEA LEVEL
SPECIFIC SPEED = N√Q / H^0.75
H = HEAD IN FEET
Specific Speed Curves For Double Suction, Single Stage, Centrifugal Pumps
HEAD IN FEET
SPECIFIC SPEED
SUCTION LIFT
SUCTION HEAD

Fig. 1. Upper limits of specific speeds for double suction, single-stage centrifugal pumps

their hardness and consequent ability to resist rolling friction.

Thrust Bearings

The Kingsbury type of thrust bearing is one generally used in centrifugal pumps. It is an oil bearing with a plain collar forming one bearing member and pivoted segments forming the other. The segments, or shoes as they are commonly called, are free to tilt slightly in any direction. This permits the oil films to assume the natural wedge shape whereby the load is "floated" without metallic contact. The shoes are always mounted in a manner to distribute the load equally among them. This construction enables high bearing pressures to be carried with low friction losses and with great durability even at high speeds.

Hydraulic Balance

Pumps of the single-suction type sometimes employ a hydraulic balance instead of, or in addition to, a thrust bearing, which may be either the balanced disk type or the balanced drum type. The balanced disk type is shown in Fig. 2.

The balancing disk (4) is fixed on the shaft back of the last stage impeller, and the face of the disk rotates normally close to the seat (2) with a film of the liquid handled by the pump in the clearance space (3) separating the disk and seat. The hub of the balancing disk extends through the thrust plate (1), which is a stationary plate held in the casing, leaving an annular opening (5) between the hub of the balancing disk and the thrust plate. The operation is as follows:

The pump when operating generates a total pressure (P), which builds up a pressure slightly less than (p) in the pressure chamber (6) by leakage through the space (5). This pressure acts against the balancing piston (4) to counterbalance the end thrust, which is in the opposite direction. If this balancing force overbalances the end thrust, the leakage joint (3) opens slightly, allowing the escape of a small volume of liquid, which is piped back to the suction, thereby reducing the pressure in the space (6) and allowing the shaft to return to a position of equilibrium. This slight end movement of the shaft is only noticeable in starting, as the shaft takes up and remains in a balanced condition when the pump is operating.

Double Volute Case Pumps

Unbalanced pressure forces acting upon an impeller are often ignored by designers of single-stage centrifugal pumps, and occasionally are disregarded even in pumps of multi-stage design. These forces at partial capacity may exceed the load placed on the shaft by its own weight, plus that of the impellers, by as much as 500 to 1000 percent. Failure of the designer to protect against such unbalanced forces, which occur when pumps operate at other than their efficiency point, results in and is evidenced by eccentric wear of the stationary parts and premature shaft failure.

The explanation of this phenomena will indicate to the pump user steps required in the control of his process to avoid such undesirable conditions, or if that is impracticable, will enable him to select equipment that will not be adversely affected by such process conditions.

Efficient operation of a centrifugal pump depends on designing passageways through the impeller and the

GENERAL OFFICES
120 BROADWAY
NEW YORK

•

AMERADA PETROLEUM CORPORATION

•

BEACON BUILDING
TULSA, OKLAHOMA

417 SOUTH HILL STREET
LOS ANGELES, CALIF.

MERCANTILE NATIONAL BANK AT DALLAS

Deep in the Heart of the Oil Industry

*** Strategically located, in the approximate center of the vast Mid-Continent area, this bank has specialized in financial service to the Oil Industry for a great many years. We invite you to call on us for any banking service you might need.

•

MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

volute section of the case, so proportioned and shaped that liquid entering the suction of the pump and passing through the impeller to the volute case is accelerated and decelerated at a uniform rate without abrupt changes in direction of flow. It is equally important that the discharge from the impeller periphery to the volute case be free from abrupt changes of velocity or direction of flow. The volute passageways of the case are, therefore, carefully shaped so that the pressure at any point is constant under conditions of normal capacity, and when the flow through the case and impeller is nearest these ideal conditions the pump operates at its maximum efficiency.

For any other conditions of flow, the relative velocities and pressures in the impeller and the volute case necessarily change. The shape of the passageways cannot be altered to accommodate this changed flow, however, and the liquid, as it leaves the impeller periphery, must make abrupt changes of direction that result in liquid impact and pressure losses. Pressures in the volute case under these conditions become unequal. These pressures of varying intensity around the periphery of the impeller produce a resultant radial force upon the shaft, which under certain conditions, can equal five to ten times the weight of the rotating parts. As this force is proportional to the pressure, impeller diameter, and width, it becomes an important element of the shaft load on large capacity pumps when impeller widths are great and the units operate at other than their most efficient operating point. This unbalanced force deflects the shaft until contact is made with the stationary parts, resulting in their eccentric wear, after which further high-speed deflections induce fatigue stresses in the shaft, causing ultimate failure.

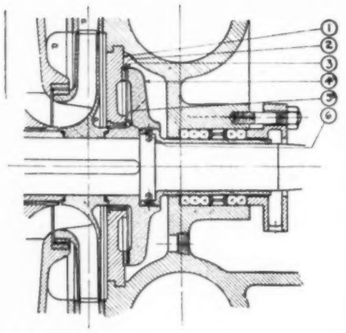


Fig. 2. Cross-sectional view of hydraulic balancing disk

By use of the double volute case, compensation for this inherent problem of a centrifugal pump is made in the design of:

(a) Pumps in which the impeller is of such size that the radial pressure forces would produce undue loading of the shaft.

(b) Multi-stage pumps in which the shaft is of such length that the deflecting forces would bend the shaft more than the pump clearances would permit.

The basic design of the double volute case divides the flow from the impeller at points 180 deg. apart. The liquid from one side flows into one volute; the liquid from the other side flows into a second volute. Both flows are directed together at the discharge. By this design, if the flow is such that a low pressure area exists in one part of either volute, there will be diametrically opposite a similarly-shaped volute with similar flow conditions in it, and, therefore, similar pressure conditions. By this means all radial pressure forces exerted upon the impeller are balanced by equal and diametrically opposite forces.

Unless it can be determined definitely that a particular pump will always operate at or near its peak efficiency, the engineer making the pump selection should assure himself that the design of the pump gives adequate protection against this potential trouble.

Look for the *Arm-and-Hammer*

ARMSTRONG BROS.

This is no time to experiment with pipe tools

Standardize on "ARMSTRONG BROS.", the better pipe tools, marked with the "Arm-and-Hammer" trade mark. Tools with the quality that has put ARMSTRONG TOOL HOLDERS into over 96% of the machine shops and tool rooms . . . stronger pipe tools, designed after exhaustive break-down tests have exposed the weaknesses of other makes . . . the tools generally known as "The Better Pipe Tools" because of their hardened steel alloy and drop forged parts, added wherever they would add strength or tool life.

Write for C-39 Catalog

ARMSTRONG BROS. TOOL CO.

"The Tool Holder People"

331 North Francisco Avenue Chicago, U. S. A.

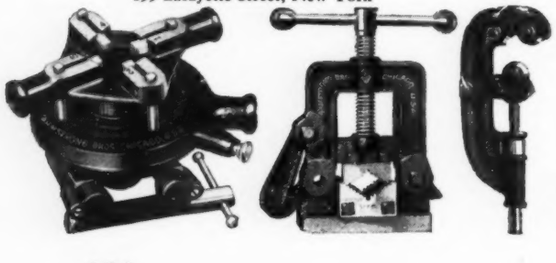
Eastern Warehouse and Sales

199 Lafayette Street, New York

ARMSTRONG BROS. Tongs have Drop Forged Jaws, Hardened, Tempered and Tested for Wearing Quality. Forged Handles, high-carbon steel, Large Hardened Bolt.

The Most Complete Line Manufactured

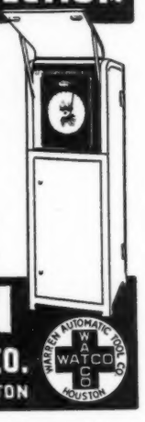
Lead seal on each chain indicates that it has been proof-tested. . . 3,600 to 40,000



"Mud-O-Graf"

LOWER MUD COSTS AND BLOWOUT PROTECTION

Intelligent, economical, scientific Mud Control necessitates constant surveillance. The Mud-O-Graf gives you this through continuous weight recording. Now used by leading producers. Needs no special operator.



WARREN AUTOMATIC TOOL CO.

2104 LEELAND AVE · HOUSTON

The Petroleum Engineer

. . . a Magazine of Methods for Operating Men

SUBSCRIPTION

1 year $2.00 . . . 2 years $3.00

P. O. BOX 1589

DALLAS TEXAS

Pressure Variations and Radial Pressure

Actual pressure readings taken in the volute of a pump case at the points indicated in Fig. 3 are plotted in the curves shown in Fig. 4. Note that only at the peak efficiency of the pump are the pressures substantially in balance.

The resultant of the unbalanced pressures is a radial force upon the impeller, which tends to deflect the shaft. This force is approximately proportional to the product of the pressure developed by the pump, the impeller diameter, and the overall width of the impeller, and may be expressed by the following approximate formula:

$$F = K \times P \times D \times W$$

Where:

F = radial pressure force, lb.,
P = pressure developed by the pump, lb. per sq. in.,
W = overall width in inches of the impeller,
D = impeller diameter, in., and
K = an empirical constant.

Experiments indicate the following average values of constant K:

At 0 percent capacity at peak efficiency, K = 0.15.

At 50 percent capacity at peak efficiency, K = 0.085.

At 100 percent capacity at peak efficiency, K = 0.00.

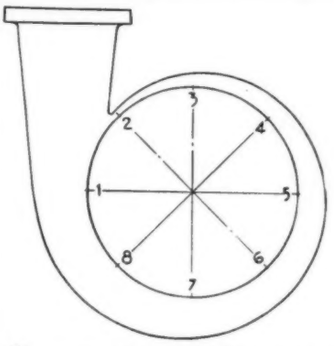


Fig. 3. Sketch of volute case with points at which pressure plotted in Fig. 4 are numbered

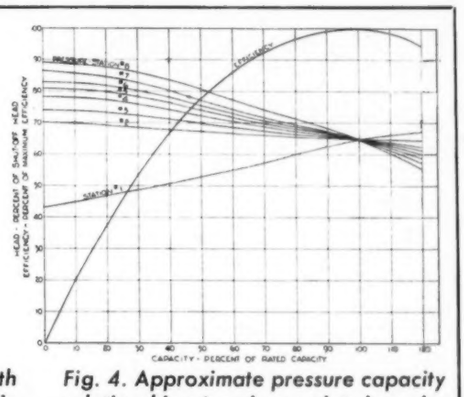


Fig. 4. Approximate pressure capacity relationship at various points in a single volute case illustrated in Fig. 3

In addition to the radial pressure force, the rotating element is subjected to its own weight and also to a momentum force (of relatively small magnitude), which have not been taken into consideration in the constant K.

Starting

A high or medium head centrifugal pump when primed and operated at full speed with the discharge valve closed requires much less power than when operating at its rated capacity and head with the discharge valve open. For this reason, it is advantageous that the discharge valve always be closed when the pump is being started, except as noted below. It is to be noted, however, that, in general, the lower the normal operating head, the less does the closing of the discharge valve affect the power required at normal capacity. At extremely low heads, such as for low-head, large-volume irrigation pumps, the shut-off hp. may equal or even exceed the hp. required with the discharge valve open.

Reduced Voltage Starting

With smaller sizes of pumps driven

Pulling for Victory In Industrial Drives

Rockford Clutches

O-C and Spring-Loaded

PLATE CLUTCHES

Used in tractors, power units, shop trucks, locomotives, conveyors, many other industrial drives.

Rockford Clutches pull for Victory in many kinds of production and power equipment; promoting peak output of armament, food, machinery, materials, other war-essentials. Illustrations show typical Rockford Clutches; suggest a few of many uses. Highly efficient and durable, compact, accurately made, listed in many standard sizes; Rockford Clutches simplify designing and installation, save every way.

Single-Type Pullmore

PULLMORE Multiple-Disc

Used in machine tools, process machinery, hoisting mechanisms, all multiple-disc clutch services.

Rockford Power Take-Offs

Rockford Plate Clutches, Over-Center and Spring-Loaded, effectively handle applications from 1 to 80 h.p. at 100 r.p.m. Investigate also *Rockford Power Take-Offs* for S.A.E. housings.

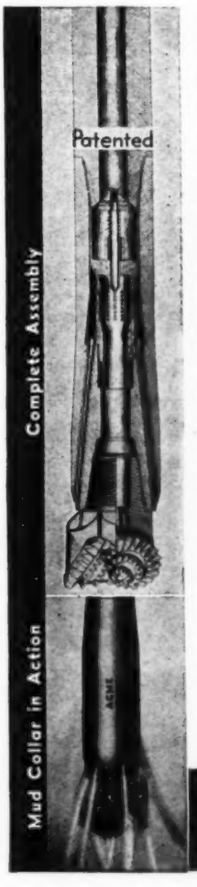
Pullmore Clutches meet all multiple-disc requirements up to 90 h.p. at 500 r.p.m. Unexcelled for high speeds, compact space. Details on request.

Double Type Pullmore

Rockford Drilling Machine Division Borg-Warner Corporation

▼ 1303 Eighteenth Avenue, Rockford, Illinois, U. S. A. ▼

Over-Center Clutches • Spring-Loaded Clutches • Pullmore Clutches • Power Take-Offs



Let Acme's New MUD-COLLAR Help You Lick the Materials Shortage Problem!

ACME DRILLING FISHING TOOLS

A product which will reduce wear and tear will not only soon pay for itself and protect profits but — *most important* — it will help relieve TODAY'S material shortage emergency. Acme's MUD COLLAR, the "modern-marvel" tool for rotary drilling, will do just THAT. And here are some definitely proven reasons why:

In any formation: It lessens drill pipe torque; assures faster, easier cutting, longer runs, fewer "green bits" and makes better hole . . . Its 6 high-velocity fluid streams keep cutters clean, bit bearings "lubricated" and free of cuttings — while constantly flushing bottom . . . In sticky formations, it also prevents mud rings and "balled up" bits. Write NOW for full information about this "wonder tool"—that will help you decrease your material purchases by increasing the life of your bits and drill pipe.

Also makers of the Famous "Drillmor" Line of Drilling and Fishing Tools for Cable Drillers—The World's Standard of Quality Since 1900

Defense comes FIRST—with most of Acme's facilities now devoted to "essential production." But we'll serve YOU as best we can . . . and "friendly-like."

Ask for Complete Catalog No. 12 — and Valuable Drillers' Manual.

The Acme Fishing Tool Co.

PARKERSBURG, WEST VIRGINIA

Expert Office: 19 Rector St., New York, N. Y.

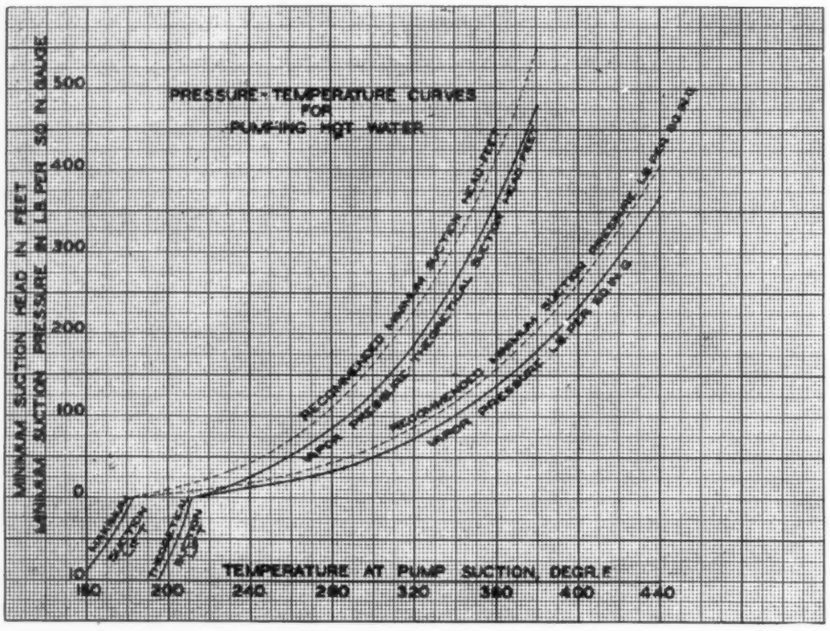


Fig. 5. Pressure-temperature curves for pumping hot water

by a squirrel-cage induction motor it is often permissible to start the motor on reduced voltage with the gate valve open, if the torque conditions of the motor permit such starting and there is no likelihood that injurious liquid hammer will exist when changing the motor over from the starting position to the running position. To close the gate valve is usually so easy that there is little need to impose a high torque mechanical strain on the rotor or to cause the inevitable high momentary wattless current demand by failure to close the discharge valve when starting. Although this wattless current does not register on the wattmeter, it does require extra copper size and transformer capacity to avoid excessive drop in line voltage.

Across-the-Line Starting

The across-the-line starting type of motor is more widely used in recent years, particularly in the smaller sizes. This type of motor obviates the necessity of starting the unit with reduced voltage through a compensator or auto transformer, but even with across-the-line starting, the length of time of the disturbance on the line, due to the starting condition, will be shortened if the valve is closed in starting.

Synchronous Motor Drive

Synchronous motors of the general purpose sizes up to and including 600 hp. at unity power factor, having speeds of 500 r.p.m. or higher, are designed with sufficient pull-in torque to start pumps with the discharge valve open. The comments already made on squirrel-cage motors apply also to the synchronous type, however.

. . . and you'll be able to get parts for . . . . . **JENSEN JACKS!**

We are the oldest and largest exclusive manufacturer of pumping equipment in the business . . . which makes owning a JENSEN JACK a very comfortable thing at a time like this. You know you have a dependable unit, and you know that parts will be available if they should be needed.

They are saving money for producers everywhere, these JENSEN JACKS. Why don't you see your JENSEN dealer or write - wire - phone us at Coffeyville?

JENSEN
BROTHERS MFG. CO.
Coffeyville, Kansas, U. S. A.
Export Office: 50 CHURCH STREET, NEW YORK CITY

PIPE LINE CONSTRUCTION
IN THE SOUTH

LATEX CONSTRUCTION CO.

Oil and Gas Building

HOUSTON, TEXAS

LAURENCE H. FAVROT GEO. A. PETERKIN

ON WHICH

of these 6 jobs can Oakite cleaning save money for you?

1. **Cleaning Heat Exchangers**
2. **De-Scaling Diesel Cooling Systems**
3. **Cleaning Tank Car Interiors**
4. **Salvaging Valves and Fittings**
5. **Reconditioning Oil, Grease Drums**
6. **Steam Cleaning Pumps, Trucks, Etc.**

Because Oakite materials are specially designed for these specific maintenance jobs, leading producers and refiners find Oakite cleaning is faster, more thorough, more economical. Why not try it and see? Start doing any one or more of these jobs the Oakite way... and the results will speak for themselves! Write for FREE booklets and data sheets.

Manufactured only by

OAKITE PRODUCTS, INC., 48 Thames St., New York

Representatives in All Principal Cities of the U. S. and Canada

OAKITE Specialized **CLEANING**

MATERIALS · METHODS · SERVICE — FOR EVERY CLEANING REQUIREMENT

STEADY PRESSURE READINGS..

. . . from a distance of 30 feet or more!

The Abercrombie Pressure Gauge is not affected by external vibrations. Pump pulsations are dampened over the entire pressure range without adjustments. Billboard figures behind a colorless, unbreakable plexiglass face are read at a glance. Little wonder drillers all like the ABERCROMBIE PRESSURE GAUGE. It has definitely taken pressure gauging out of the delicate instrument class.

ABERCROMBIE PUMP COMPANY
Gulf Building : Houston, Texas

ABERCROMBIE PRESSURE GAUGE

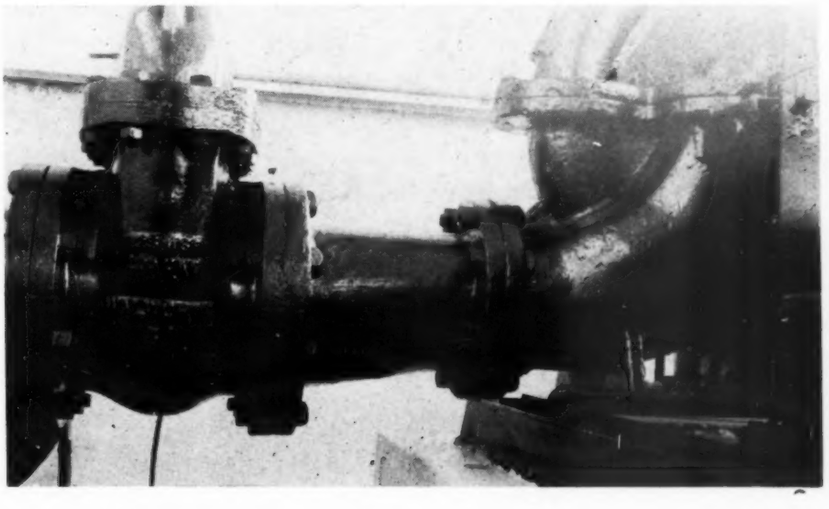
Wearing Rings

Wearing rings are fitted in the casing and on the impeller around the inlet to reduce the quantity of liquid leaking back from the high-pressure side to the suction side. These wearing rings are fitted with a small clearance and depend on the liquid in the pump for lubrication. This is the reason that a centrifugal pump should never be run unless the case is filled with liquid. The rings will eventually wear so that the clearance becomes greater and more liquid passes back into the suction. Note that the amount of this leakage is a function of the differential between the suction and discharge pressures of each stage and the necessity of renewing the rings is governed largely by this differential. The rate of wear depends on the corrosive and abrasive qualities of the liquid being pumped.

Temperature and Suction Pressure

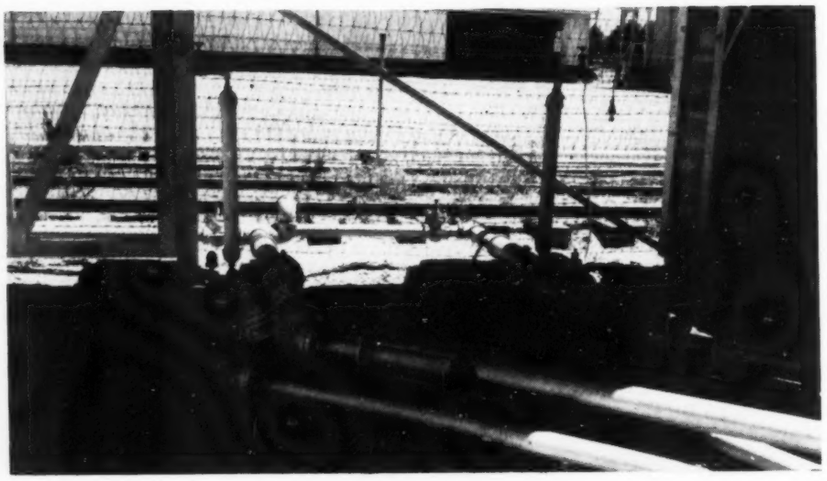
Whether the liquid to be handled in a centrifugal pump is water or a petroleum fraction, the temperature of that liquid and the effect of that temperature upon its vapor pressure are factors that must be considered when calculating the suction pressure at the pump. To provide a positive suction head barely high enough to prevent formation of vapor at the flowing temperature is not enough. There must be an excess pressure to take care of friction losses in the suction passages and impeller inlet of the pump. For example, when pumping hot water at a temperature of 212°F., the boiling point of water at sea level, the theoretical suction lift under which a pump could operate would be zero feet. In practice it is never possible to approach this figure due to the velocity losses at the entrance to the pump and the internal pump losses. Consequently, a certain pressure in excess of the vapor pressure of the water must be maintained at all times.

Curves shown in Fig. 5 give the



Eccentric reducer in water pump suction

Flexible couplings removing pipe strain from pumps



theoretical and recommended maximum suction heads to be maintained for various temperatures. This is based on a suction pressure of 14 ft. in excess of the vapor pressure of the liquid, plus a safety factor that is figured as the difference in vapor pressure that would be caused by a 2 percent change in the liquid temperature. For boiling water at 212°F. this gives a total recommended suction head of 16 ft., and for 400°F. water a suction head of 707 ft.

Deep-Well Turbine Pump

The conventional deep-well turbine pump has been used for many years and the only serious objection to it has been the difficulties that were bound to occur from the long shaft extending from the drive unit at the surface to the pump itself, which would, of course, be some distance below the lowest liquid level. To maintain proper alignment of a long shaft required many bearings placed on relatively short centers in brackets inside the discharge column. To pack these bearings against the pumped fluid, which might contain sand, etc., was also difficult. Further, to perform any repairs upon the pump itself or upon any of the bearings necessitated "pulling" the well.

Oil-Lubricated Type Discharge Column

Most of the trouble arising from sand entering the bearings has been obviated by the development of the inner pipe or housing idea. This is a column designed for oil lubrication and consists of an outer and inner pipe, the latter housing the vertical lineshaft. Oil supplied by gravity feed from the surface provides lubrication to the lineshaft bearings.

At the lower end of the discharge column an automatic stuffingbox and drain port are provided in the top case of the pump to prevent entrance into

ANNOUNCEMENT

Conservation of scarce metal is demanded as a part of the victory effort. In order to do our part in this conservation program, our stocks of carburetion equipment and parts must be held to a minimum.

Effective July 1, we will close our Dallas Branch for the duration.

Complete stocks will be maintained at our Chicago Branch, 2644 South Michigan Avenue, Chicago, and at our Main Office at 7010 South Alameda Street, Huntington Park, California.

Address the office nearest you where we will endeavor to give the same service our Dallas Branch has rendered in the past.

YOURS FOR VICTORY

ENSIGN
CARBURETOR CO., LTD.
HUNTINGTON PARK, CALIF. • DALLAS, TEXAS • CHICAGO, ILL.

In Los Angeles—
Live on the sea-cooled crest of Wilshire

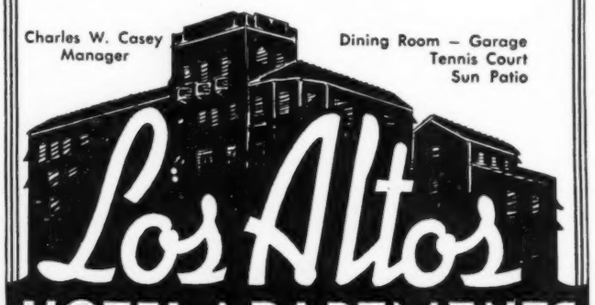
Luxurious accommodations at sensible rates. Located midway between Hollywood, Beverly Hills, the Beaches and downtown Los Angeles.

APARTMENTS, Daily Maid and 24-Hour Switchboard Service from $5 dly.; $90 monthly. Suites from $6 dly.

HOTEL ROOMS, from $3 daily

Charles W. Casey
Manager

Dining Room — Garage
Tennis Court
Sun Patio



Los Altos
HOTEL APARTMENTS
4121 WILSHIRE BOULEVARD . . . NEAR CRENSHAW
LOS ANGELES, CALIFORNIA
Same Ownership Harrison Hotel, Chicago

the inner tube of the pumped liquid. The inner pipe couplings are of bronze and serve not only to connect the sections of the inner pipe, but also act as bearings for the shaft. These bearings are placed on short centers (usually about 5 ft.) thus reducing any tendency of the shaft to whip. On long columns rubber bushed spiders are placed at intervals, providing added support to the inner column, which is placed under tension after erection.

This arrangement has worked out very satisfactorily and has come into widespread use, particularly when the drive cannot be by electric motor.

The Submersible Pump

The natural solution was to make the motor integral with and below the pump. Conventional ideas of necessary diameter of rotor of an induction motor, however, made this seem impracticable because of the added cost of the larger diameter well and casing.

Efforts to work out a successful design of rotor with a diameter within the usual limits of a well and casing met with little success, perhaps because the idea was so generally considered impossible. The problem was finally solved by one of the prominent pump manufacturers and the equipment is now widely used, not only for deep-well water pumping but also for a more recent and very valuable appliciation: that of gasoline or oil pipeline pumping under conditions vulnerable to aerial or land attack. The unit requires no above-surface control equipment, either electrical or mechanical, consequently its location can be completely concealed and given full protection against bombing. The advantages of these features are too obvious to require elaboration.

The submersible pump is finding further application in handling volatile fractions in refineries. When the conditions are such that it may be completely submersed it is reported to be capable of handling wilder stocks than the conventional horizontal process pump especially designed for this purpose. Absence of a stuffingbox, obviously gives a better safety factor.

These submersible units had to overcome an enormous prejudice before they became generally accepted. The basis of the prejudice was the well-grounded fear of submersing electrical apparatus in a liquid.

High-Vapor-Pressure Liquids

One of the more recent developments in centrifugal pumps that is of pertinent interest to oil refineries is the adapting of the centrifugal pump to handle some of the lighter and more volatile petroleum fractions. The hot oil centrifugal pump has been in general use for some years, but the problem in that case was more in the nature of withstanding high temperatures than of combating a vapor condition, as adequate suction pressure was usually available to insure a liquid condition of the oil.

In the handling of volatile gasolines or butane, for example, this suction pressure is not always availabile. Recourse was taken, generally, to a low clearance displacement pump. This had certain manifest disadvantages. Centrifugal pumps have now been developed for this purpose and are in common use.

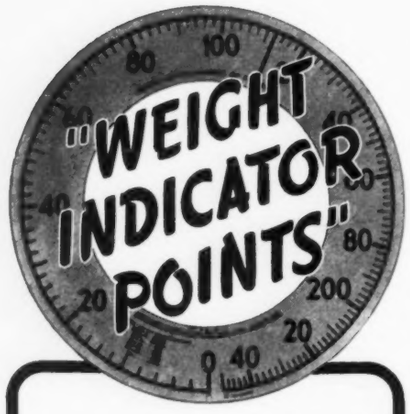
Acknowledgment

The writer wishes to acknowledge the courtesy of the Hydraulic Institute and their permission to use the valuable illustrations and other material in their Standards Handbook. Certain pump manufacturers also extended their aid in the same manner, as well as in checking the manuscript.

——— ☆ ☆ ☆ ———

Perfect Sealing IN THE PRESENCE OF GRITTY OR CORROSIVE CONDITONS
COMPRESSION SPRINGS
SEAL RING
SHAFT PACKING
STUFFING BOX
GLAND
GLAND INSERT
SHAFT
COLLAR
GASKETS
SET SCREWS
COMPRESSION RING
DRIVE PIN
DURA SEAL
A MECHANICAL SEAL FOR CENTRIFUGAL OR ROTARY PUMPS AND AGITATORS.
Leading operators have adopted DURA SEAL as the most effective seal on the market today for gritty or corrosive liquids and gases. Applicable in standard stuffing boxes. Rotates with the shaft—no scoring of shaft. No sleeves needed. Friction 1/6th that of ordinary packings. DURA SEAL is meeting many difficult sealing requirements in Oil Refineries, Chemical Plants, Distilleries, Paper Mills and general industries.
WRITE TODAY FOR DURA SEAL BULLETIN AND SPECIFICATION BLANKS.
The PERFECT SEAL
DURAMETALLIC CORPORATION
KALAMAZOO MICHIGAN

POWER to WIN!
In terms of man-hours saved, and productive capacity of machines increased . . . Wisconsin heavy-duty air-cooled engines are supplying the United Nations and Industry-at-Large with the Power to Win!
A complete range of sizes, from 1 to 35 hp., 1 and 4-cylinder models.
MOST POWER Per POUND
WISCONSIN MOTOR Corporation
MILWAUKEE, WISCONSIN, U.S.A.
World's Largest Builders of Heavy-Duty Air-Cooled Engines
WRITE TO HARLEY SALES CO.
510 ATLAS BLDG., TULSA, OKLA.
M & M BLDG., HOUSTON, TEXAS
OIL FIELD DISTRIBUTOR FOR WISCONSIN ENGINES AND ALL TYPES OF UTILITY UNITS
A 3707-¼



FLYING BLIND is dangerous for even the best pilots and is done only when unavoidable.

DRILLING BLIND, too, is dangerous with even the best driller at the draw works . . . but need NEVER be done!

For with a Martin-Decker "Sealtite" your driller knows where he is going at all times. It helps him keep his weights, torque, speeds, and pressures in proper ratio for straighter, safer hole.

Steel and oil will win this war. Take extra precautions with your equipment!

MARTIN-DECKER CORP.

LONG BEACH, CALIFORNIA

SAN JOAQUIN VALLEY: A. F. McQUISTON, BAKERSFIELD, CALIFORNIA
MID-CONTINENT DISTRIBUTOR: REED ROLLER BIT CO., HOUSTON, TEXAS

Index to Advertisers

	Page
Abercrombie Pump Co.	189
Acme Fishing Tool Co.	187
Air Reduction Co., Inc.	141
Amerada Petroleum Corp.	185
American Air Filter Co., Inc.	159
American Cable Division of American Chain and Cable Company, Inc.	Inside Back Cover
American Chain & Cable Company, Inc.	Inside Back Cover, 17, 89
American Hammered Piston Ring Division	7
American Roller Bearing Co.	41
American Sand-Banum Co., Inc.	183
Armstrong Bros. Tool Co.	186
B and W, Inc.	180
Baash-Ross Tool Co.	38
Baker Oil Tools, Inc.	133
Baldwin De LaVergne Sales Corp.	93
Bantam Bearings Corp.	20
Baroid Sales Co.	12
Bartlett-Hayward Division	7
Brown Instrument Co.	107
Buckeye Traction Ditcher Co.	137
Bullard, E. D., Co.	183
Cameron Iron Works	67
Cardwell Mfg. Co.	1
Carlyle Rubber Co., Inc.	184
Chapman Valve Mfg. Co., The	10
Chiksan Tool Co.	127
Clark Bros. Co.	72-73
Cleveland Trencher Co.	95
Continental Motors Corp.	166
Continental Supply Co., The	65
Cook, C. Lee, Mfg. Co.	80
Cooper-Bessemer Corp.	35
Cooper, Fred E.	70
Coy, Joseph A., Co., Inc.	177
Crane Co.	15
Cummins Engine Co.	138
Curtin, W. H., & Co.	183
Durametallic Corp.	191
Edward Valve & Mfg. Co.	98
Electro Metallurgical Co.	77
Engineering Laboratories, Inc.	155
Ensign Carburetor Co., Ltd.	190
Fisher Governor Co.	103
Fluid Packed Pump Co.	117
Foster Wheeler Corp.	109
Franks Mfg. Corp.	131
General Paint Corp.	171
Graver Tank & Mfg. Co., Inc.	105
Gulf States Utilities Co.	169
Halliburton Oil Well Cementing Company	Back Cover
Haynes Stellite Company	165
Hazard Wire Rope Division of America Chain and Cable Co., Inc.	17
Hill, Hubbell & Co., Division	171
Hudson Engineering Corp.	100-101
Hughes Tool Co.	49
Hunt Tool Co.	45
Hyatt Bearings Division, General Motors Sales Corp.	13
Jensen Bros. Mfg. Co.	188
Jones & Laughlin Steel Corp.	153
Jones, S. M. Co.	170
Keuffel & Esser Co.	61
Koppers Company	7
Latex Construction Co.	188
LeRoi Company	143
Leschen, A., & Sons Rope Co.	19
Link-Belt Co.	51
Lone Star Cement Corp.	39
Los Altos Hotel	190
Lufkin Rule Co.	160
Lunkenheimer Co., The	16
Macwhyte Company	3
Marmon-Herrington Co.	11
Martin-Decker Corp.	192
Mercantile National Bank at Dallas	185
Merco-Nordstrom Valve Co.	Front Cover
Merla Tool Corp.	79
Midwest Piping & Supply Co., Inc.	113
Mission Mfg. Co.	121
National Carbon Company, Inc., Carbon Sales Division	14
National Supply Co., The	21
O.C.S. Mfg. Co., The	54
Oakite Products, Inc.	189
Ohio Injector Company	161
Oil Well Supply Co.	129
Otis Pressure Control, Inc.	59
Pacific Pump Works	178
Patterson-Ballagh Corporation	182
Penberthy Injector Co.	135
Petroleum Electric Power Assn.	163
Petroleum Rectifying Co.	63
Pittsburgh-Des Moines Steel Co.	87
Pritchard, J. F., & Co.	144
Reading-Pratt & Cady Division of American Chain & Cable Co., Inc.	89
Rector Well Equipment Co., Inc.	47
Reed Roller Bit Co.	22
Reilly Tar & Chemical Corp.	167
Republic Steel Corp.	Inside Front Cover
Ridge Tool Co.	6
Rockford Drilling Machine Division	187
Schlumberger Well Surveying Corp.	151
Shaffer Tool Works	123
Smith, O. A., Corp	119
Southern Mill & Mfg. Co.	57
Southwestern Gas & Electric Co.	168
Spang & Company	114
Sperry-Sun Well Surveying Co.	125
Staynew Filter Corp.	8
Taylor Forge & Pipe Works	149
Texaco Development Corp.	83
Tretolite Co.	2
Tube-Turns, Inc.	147
Twin-Disc Clutch Co.	172
Union Carbide and Carbon Corp.	14, 77, 165
Unit Rig & Equipment Co.	5
United Gas Pipe Line Co.	176
U. S. Steel Corp. Subsidiaries	129
Visco Products Company, Inc.	69
Vogt, Henry, Machine Co., Inc.	111
Vortox Manufacturing Company	181
Wagner Electric Corp.	97
Wall-Colmonoy Corp.	173
Warren Automatic Tool Co.	186
Waukesha Motor Company	37
Whitney Chain & Mfg. Co., The	156
Williams, J. H., & Co.	174
Wilson Supply Co.	91
Wisconsin Motor Corp.	191
Wyatt Metal & Boiler Works	75
Young Radiator Co.	181
Youngstown Sheet & Tube Co.	9
Zachry, H. B., Company	53

American Hammered Piston Ring Division, Bartlett Hayward Division, Engineering and Construction Division, Wood Preserving Corp., The